

Development of modified starch technology (*maltodextrin*) from commercial tapioca on semi production scale using oil heater dextrinator

Agus Triyono, Raden Cecep Erwan Andriansyah, Rohmah Luthfiyanti, Taufik Rahman

Development Center for Appropriate Technology – Indonesian Institute of Sciences
Jl. KS Tubun No 5 Subang, West Java, Indonesia

E-mail: ateluyono@gmail.com

Abstract. One way to improve functional starch is by modification of starch into dextrin or maltodextrin. Maltodextrin is used in the food industry as a food substitution. Development of enzymatically modified starch technology has been performed with the use of α -amylase at optimum pH of 5.5, temperature 75-85 °C, with enzyme activity of 135 KNU/g. The maltodextrin produced from commercial tapioca has the quality requirements for food according to SNI 1992. The yield of maltodextrin obtained is about 80%. The use of the optimum amount of the α -amylase enzyme is 0.07 % v/w and the substrate amount of tapioca starch is 35%. Analysis of the feasibility of modified starch with the assumption of production scale of 300 kg per day, the economic value of 10 years business, the price of starch is IDR 8,350/kg, from tapioca starch (tapioca) IDR 4,000 – IDR 4,500/kg.

1. Introduction

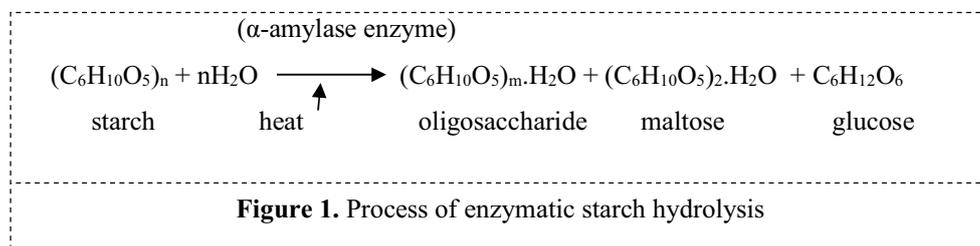
Starch utilization is widely used as an ingredient for the food and pharmaceutical industry, especially for the food industry, as substitutes, mixtures, thickening agents, and fillers. The addition of modified starch to food products can enhance the superiority and good quality of physical appearance, taste, consistency, color, and nutrients. The modified starch is the starch whose hydroxyl group has undergone a change. Modified starch can also be hydrolysis (acid and enzyme) reactions, depolymerisation, crosslinking, dextrinization and typical chemical reactions (cationization, carboxymethylation and grafting). The modified starch will experience changes in properties that can be adapted for specific purposes [1]. Desirable properties generally are starch which has stable viscosity at high and low temperature, good mechanical shearing resistance and thickness resistance to acidic and sterilization temperatures [2].

Starch is a carbohydrate group of a glucose compound polymer composed of two main fractions, those are amylose and amylopectin. Amylose is highly hydrophilic, because it contains many hydroxyl groups. Collection of amylose in water is difficult to form gel, although high concentration. Starch molecules are not readily soluble in water at room temperature or cold water, in contrast to amylopectin that structure is branched; the starch will easily expand and form colloids in water. One example of starch modification product is dextrin/maltodextrin.



Dextrin is the intermediate product of acidic or enzymatic hydrolysis process. According to [3], dextrin is a product of starch hydrolysis, in the form of amorphous substances white to yellowish. [4] states there are several levels in the hydrolysis reaction of starch. The starch molecule initially breaks into shorter glucose chain units called oligosaccharides, and when further process is broken down into maltose and eventually maltose breaks into glucose.

Maltodextrin is defined as a product of starch hydrolysis containing a unit of α -D-glucose that is largely bonded through a 1.4 glycosidic bond with a DE less than 20 [5]. The general formula of maltodextrin is $[(C_6H_{10}O_5)_n H_2O]$. Maltodextrin with water will form a gel that can melt or dissolve and resemble a fatty structure. Consistency, appearance and organoleptic properties are acceptable. The use of maltodextrin in food production can also reduce calories by more than 70 percent [6]. The process of enzymatic starch hydrolysis showed in Figure 1.



[7] The use of enzyme in the hydrolysis process is widespread due to several advantages compared with the use of acid solution. Enzyme in small quantities can decompose starch in large quantities, so the cost is relatively cheaper. [8] The enzyme works specifically, so it is easy to control, otherwise production equipment is easier than production using acid that requires acid-resistant equipment. The enzymatic hydrolysis process in starch to make maltodextrin more popular is done because it will produce a more controllable starch polymer fraction as compared to chemical processes with acid addition.

In 2002 Indonesia imports starch modification products by 80,000 tons, while import of dextrin product is estimated at 55-65% of total imports of starch modification. The price range of dextrin is US \$ 425 per ton for white dextrin and US \$ 450 per ton for yellow dextrin. Every year Indonesia's import value of dextrin and other starch modification products increases, reflecting the increasingly levels of modified starch requirements for food, pharmaceutical and cosmetics industries. Besides, the availability of sources of starch in Indonesia not only type and amount, became the background of assessment and development activities of dextrin products from sweet potato starch and starch from sources of other tubers (cassava, Garut bulbs). To produce semi-scale production dextrin done several stages of activity, namely the stage of techno-economic feasibility analysis of the planning stage of the equipment and lay out the location of the tool, And the development stage of other starch modification products such as the development of glucose and fructose manufacture, and its utilization as functional food substitution material [12].

The purpose of this study is to develop starch modification product from tuber source to semi-production scale and test technological ability of dextrinator or converter equipment shocked with heater oil heater. In order to realize the integrated technology package of modified starch of cassava starch (tapioca) at semi-production scale with quality requirement meets the requirement of dextrin quality for SNI food 1992 (Indonesian National Standard).

2. Research methods

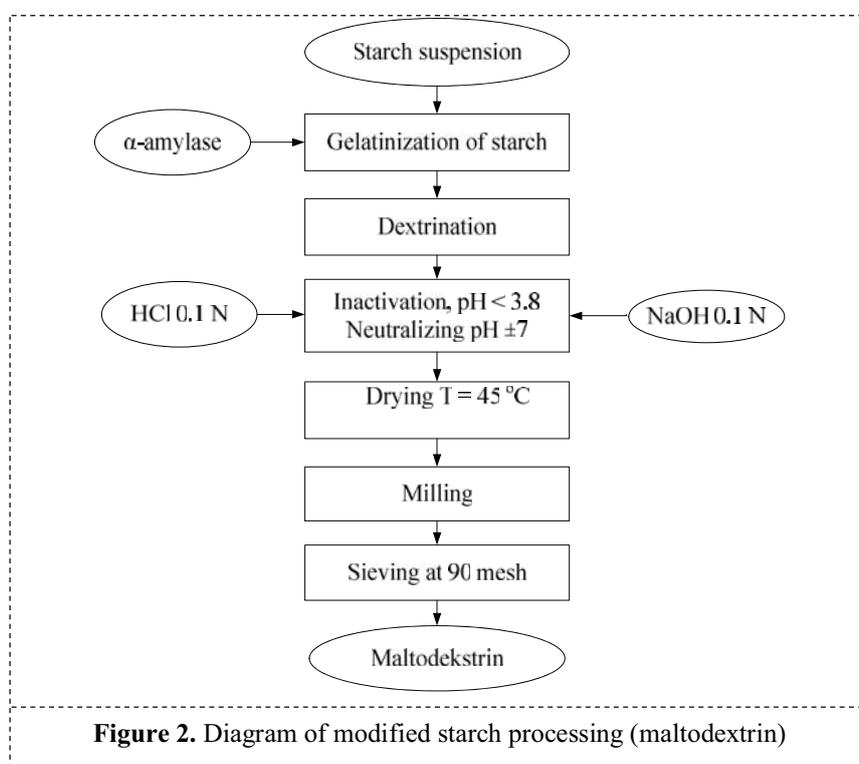
2.1. Materials and equipment

2.1.1. Material. Fresh cassava material obtained from around the Subang rency and commercial bulk tapioca starch is obtained in the general market. Commercial α -Amylase enzyme, from thermal enzyme type from *Bacillus licheniformis* [14] is a solution (liquozyme supra) with activity of 135 KNU/g from Halim Sakti Pratama Company. In experimentation of the process of making modified starch (maltodextrin) by enzymatic method, to determine the amount of enzyme and the amount of optimum starch substrate with variation of concentration and process temperature, at pH 5.5 .0 (optimum). The main experiment is the trial of maltodextrin production from commercial cassava starch (tapioca) on the market and using a dextrinator (converter) with heater oil heater.

2.1.2. Equipment. Solvent / shredder, hydraulic press, dryer, shifter, scale laboratory dextrinator/ converter and semi-production scale dextrinator (converter) in PPTTG-LIPI Subang

2.2. Methodology

Development of modified starch technology (maltodextrin), carried out by the following method stages (Figure 2); Determination of temperature and length of dextrination by Lugol method and spectrometry. The determination of the amount of starch substrate concentration and enzyme concentration. Furthermore, the development of modified starch technology is done by trial production at semi-production scale from commercial tapioca starch material. Physico-chemical characterization resulting from the development of modified starch technology (maltodextrin) is based on the quality requirement of dextrin for food, which is SNI (Indonesian National Standard). Semi-modified starch technology development activity in addition to physico-chemical tested, also conducted and analyzed techno economy and feasibility.



3. Results and discussion

3.1. Making starch

The stages of the starch-making process begin with cleaning, dissolving, and extraction. Separation of starch is done by precipitation for 12 hours. The upper water is removed and the precipitate is dried. The starch is still in the form of dried lumps, then milled and sifted.

3.2. Physico-chemical analysis of cassava starch

The material of cassava starch is obtained from fresh cassava around Subang regency. The result of physico-chemical characteristic starch analysis of fresh cassava from Subang regency and commercial cassava starch (tapioca) can be seen in Table 1.

Table 1. The result of physico-chemical characteristic starch analysis of fresh cassava from Subang regency and commercial cassava starch (tapioca)

No	Test criteria	Unit	Value	
			Fresh cassava starch	Cassava starch commercial
1	Water content	%	8.16	12
2	Ash content	%	0.24	0.23
3	Starch content	%	88.82	84.60
4	Fat content	%	0.21	0.64
5	Protein content	%	0.31	0.30
6	Crude fiber content	%	-	0.45
7	White degree (percent BaSO ₄)	(%)	126.22	84.1

The results of water content of cassava starch analysis is smaller than commercial starch is 8.16%, according to SNI 3451-2011 maximum water content is 15%. The results of ash content showed almost the same value of 0.23% for commercial starch and 0.24%, fresh cassava starch still included in the maximum limit of SNI 3451-2011 is 0.6%. The starch content of fresh cassava starch is greater than commercial starch which is about 88.82%. White degree for fresh cassava starch is whiter and higher value is 126.22%, where the minimum SNI value is 94.5%. Overall, the quality of fresh cassava starch and commercial starch (tapioca) produced still fulfil the quality limit requirement by SNI 3451-2011.

3.3. Experimental result of making modified starch (maltodextrin) from cassava starch

3.3.1. Making starch modified in cassava starch

3.3.1.1. Determination of temperature and length of the dextrination process. Starch will form a blue color complex when it is spilled with an Iodine reagent. According to [9], dextrin will produce a brownish red complexion if Iodine reacted. In a preliminary experiment to determine the optimum temperature and length of the dextrination process, using the thermal type α -amylase enzyme is performed on variations in the amount of starch substrate; Starting at 15%, 25%, 35%, at pH 5.5 and the amount of 0.05% (v/w) α -amylase enzyme concentration [13].

Table 2. Determination of temperature and length of dextrination based on absorbance method spectrometer from residual starch on starch substrate amount 15%

Time (minutes)	Absorbance value		
	80 °C	90 °C	100 °C
15	0.570	0.436	0.312
30	0.329	0.249	0.530
45	0.371	0.284	0.778
60	0.374	0.312	
75	0.413		
90	0.545		
105	0.657		
120	0.756		

The length of the dextrination process at the concentration of starch substrate (15%, 25%, and 35%) is more than 30 minutes. This means that the concentration of starch solution of 15% requires about 30 minutes, at a concentration of 25% starch solution takes more than 50 minutes, and at a concentration of 35% starch solution takes time About 70 minutes is enough to produce dextrin (maltodextrin) (Table 2).

Table 3. The determination of the length of dextrination based on the color change of the Iodine reagent at different starch substrate concentrations 15%, 25%, 35% and 0.05% enzyme concentration at 85°C

Time (minutes)	Substrate concentration of cassava starch (%)		
	15	25	35
0	Dark blue	Dark blue	Dark blue
20	Blue	Blue	Blue
30	Purple	Blue	Blue
40	Red chocolate	Purple	Blue purple
50		Red chocolate	Blue purple
60			Purple
70			Red chocolate

For experiment the manufacture of maltodextrin is carried out at 85 °C, and the treatment of substrate concentration (15%, 25%, 35%), and the addition of enzyme concentration varied 0.05% 0.07% 0.09%. For experiments, the manufacture of maltodextrin was carried out at 85 °C, and the treatment of substrate concentration (15%, 25%, 35%), and the addition of enzyme concentration amounted to 0.05% 0.07% 0.09% (Table 3). From the preliminary experiment results, the concentration of starch substrate and the optimum concentration of enzyme α -amylase were selected. Then the results obtained will be used in the main experiment of semi-production of maltodextrin. Equipment and production facilities such as dextrinators jacketed with an oil heater.

3.3.1.2. *Physico-chemical analysis of modified starch (maltodextrin)*. The experimental result of maltodextrin preparation from the combined treatment of the amount of starch substrate (15%, 25%, 35%), with enzyme amount (0.05%, 0.07%, 0.09%), Optimum results are from the treatment of 35% starch substrate, 0.07-0.09% enzyme concentration. The characteristics of maltodextrin are as follow; water content 4.70 – 6.42% (<11%); ash content 0.16 - 0.18% (<0.5%); and white degrees 83.30 - 93.66%, and dextrose content <5.0%, cold water solubility 97.14 - 99.35% (> 97%) (Table 4).

Table 4. Result of physico-chemical analysis of maltodextrin from cassava starch

Treatment	Parameter					
	Water content (%)	Ash Content (%)	Dextrose Content (%)	Solubility in water (%)	White Degrees (% BaSO ₄)	
a ₁ (15%)	b ₁ (0.05 %)	5.65	0.18	3.21	98.69	85.63
	b ₂ (0.07 %)	6.42	0.16	2.94	99.35	83.30
	b ₃ (0.09 %)	5.40	0.18	2.98	97.14	85.80
a ₂ (25%)	b ₁ (0.05 %)	5.05	0.18	3.85	97.17	84.40
	b ₂ (0.07 %)	5.11	0.18	3.83	97.12	87.30
	b ₃ (0.09 %)	5.38	0.18	3.24	98.29	93.66
a ₃ (35%)	b ₁ (0.05 %)	6.11	0.17	2.79	99.34	85.26
	b ₂ (0.07 %)	5.33	0.17	3.56	99.06	87.81
	b ₃ (0.09 %)	4.70	0.16	3.69	97.50	89.55
Quality Requirement For SNI Food (1992)	Max 11	Max 0.5	Max 5	Min 97	White-yellowish	

3.3.2. *Production experiment of modified starch (maltodextrin) from tapioca commercial on semi scale production*

In the preliminary trial of maltodextrin manufacture, the highest starch substrate concentration is 35% with a time of about 40 minutes. The optimal concentration of enzyme α -amylase (*Bacillus licheniformis*) 0.07% (v/b). Experiment on semi-scale production using a system of dextrinator equipment (converter) at various levels of tapioca substrate concentration. Aims to obtain optimization of the capability of producing maltodextrin, and is expected to be done on small and medium enterprises (SMEs).

The development of modified starch making technology by experimenting the production of maltodextrin from starch sources of bulb (cassava), is one of the attempts to substitute modified starch from import with domestic production using starch source from local source of tapioca (tapioca) overflow.

From the experimental results of production (Table 5) the results of maltodextrin trial experiments from various variations of the concentration of tapioca starch substrate (25%, 50%, 55%, 60%) in the amount of 0.07% (v / b) α -amylase enzyme concentration to 75%, and yield of maltodextrin rendement is increasing, and the value of DE (dextrose equivalent) is still relatively below 20. [10] The value of DE (dextrose equivalent) is the percent of reducing sugar in sugar calculated as dextrose in a dry basis. [11] The range of DE values is from 0-100. The value of DE 3-20 is owned by maltodextrin; 20-75 is owned by glucose and above 75 is referred to as hydrolyzate.

Table 5. Maltodextrin result from various concentrations of tapioca substrate using dextrinator (convert) with heater oil heater

No	Substrate starch (%)	Dextrination time (minutes)	Rendemen (%)	Water content (%)	Dextrose equivalent (D.E)
1	25	50	66	7.36	13.95
2	50	70	74	5.91	11.80
3	55	90	80	4.41	11.40
4	60	120	85	4.50	11.25
Concentration < 75%		Time <120	Rendemen <85%	Water content <11	D.E <20

The maximum limited capacity of dextrinators, is processing the maximum amount of substrate starch concentration is 60%. In the amount of starch substrate concentration more than 60%, the stirring system is experiencing difficulty because it is too thick, especially when gelatinization conditions are achieved. Subsequently, the experimental production of semi-scale maltodextrins with the use of 0.07% α -amylase enzyme concentration (v/w) in the amount of tapioca starch concentration is 35% and the result fulfilled the quality requirements of dextrin (maltodextrin) for food, that is SNI (1992) (Table 6).

Table 6. Maltodextrin analysis results from tapioca commercial

No	Parameter	Value	
		Maltodextrin from Tapioca	Requirement of Quality of Dextrin For Food, SNI (1992)
1	Color	White	White-yellowish
2	White degree (%BaSO ₄)	93.66	
3	Water content (% b/b)	5.40	Max 11
4	Ash Content (% b/b)	0.18	Max 0.5
5	Dextrose Content (%),	3.24	Max 5
6	D.E	18.40<20	
7	The part that Soluble in Cold water (%)	98.25	Min 97
8	Viscosity (cP)	-	3-4
9	Degree of acid (0,01 N NaOH/100 g)	0.80	Max 5

3.4. Economic analysis and feasibility economic business

Economic analysis and business feasibility of product or business plan from modified starch production (maltodextrin) from cassava starch (tapioca). In general, the economic viability of the business is strongly influenced by raw materials (quantity, price, and starch yield). The yield of cassava starch (tapioca) can reach more than 25% due to harvest time of more than 9 months, so that the price of cassava starch (tapioca) is around IDR 3,000 to IDR 4,500 per kg.

The heating capacity of dextrinators with oil heater to produce maltodextrin is 250-300 kg per day. The input of starch substrate concentration is a maximum of 60% and will result in a maltodextrin rendemen of about 84%. Business economic feasibility result for 10 years, selling price of maltodextrin from cassava starch (tapioca) IDR 8,360/kg with price of tapioca starch IDR 3,000-IDR 4,500/kg.

4. Conclusions and recommendations

Maltodextrin (modified starch), obtained from partial process of starch hydrolysis by using commercial α -amylase enzyme, from a number of starch concentrations (about > 35%) of commercial cassava starch (tapioca) is widely available. The experimental production of maltodextrin (enzyme starch) enzymatically with commercial α -amylase enzyme, from *Bacillus licheniformis* (activity 135 KNU/g) is optimum at pH 5.5 and temperature 85 °C.

The results obtained in the development of technology of making modified starch (maltodextrin) from cassava (tapioca) enzymatically fulfilling SNI quality requirements for food (SNI, 1992), and for non-food (SNI, 1989). The yield of maltodextrin was obtained about 80%, from the use of enzyme α -amylase (*B. licheniformis*) 0.07% v/w on 35% tapioca starch substrate. Modified starch feasibility analysis is production capacity 300 kg per day and 10 years economic value for maltodextrin from tapioca starch, with the selling price IDR 8,360/kg.

Acknowledgment

The authors would like to thank to the contribution of Oktiana Palupi from Padjajaran University, Siti Kudhaifanny from PPTTG-LIPI for assistance in the development of modified starch not only the laboratory scale but also the semi-production scale.

References

- [1] Fleche G 1985 Chemical modification and degradation of starch In: G. M. A. Van Beynum and J A Roles (eds.) *Starch Conversion Technology* Marcel Dekker Inc. New York and Bassel.
- [2] Wurzburg O B 1989 *Modified starches: properties and uses* CRC Press Inc Boca Ranton Florida
- [3] Dewan Standarisasi Nasional 1992 *Dekstrin untuk industri non pangan* Jakarta.
- [4] Gaman P M and Sherrington K B 1992 *Pengantar ilmu pangan nutrisi dan mikrobiologi*. Translation Gadjah Mada University Press Yogyakarta.
- [5] Griffin V K and Brooks J R 1989 Production and size distribution of rice maltodextrin hydrolyzed from milled rice flour using heat stable alpha amylase *Journal of Food Science* **54** 190-193.
- [6] Roper H 1996 Starch: present use and future utilization in: Van Bekkum, H. H. Ropper and A. G J Voragen (eds.) *Carbohydrates as organic raw materials III* VCH Publisher Weinheim.
- [7] Pomeranz Y 1991 *functional properties of food components* 2nd edition Academic press.
- [8] Tjokroadikoesoemo P S 1986 *HFS dari industri ubi kayu dan umbi lainnya* Gramedia Jakarta.
- [9] Winarno F G 2002 *Kimia pangan dan gizi* PT Gramedia Pustaka Utama Jakarta.
- [10] Kennedy J F, Knill C J and Taylor D W 1995 Maltodextrins in : Kearsley, M.W.J. dan Dziedzic, S.Z., (eds.) *Handbook of starch hydrolysis product and their derivatives* Blackie Academic & Professional London Chapter **3** 65-83.
- [11] Kearsley M W and Dziedzic S Z 1995 Physical and chemical properties of glucose syrup. *Di dalam* : Kearsley, M.W.J. dan S.Z.Dziedzic (eds.) *Handbook of Starch Hydrolysis Product and Their Derivatives*. Blackie Academic & Professional, London. Chapter **5**. 129-154.
- [12] Triyono A 2008 Karakteristik hasil optimalisasi usaha produksi pati termodifikasi secara enzimatik dari umbi-umbian dengan konverter sistim pemanas berjaked oli. *Prosiding Seminar Nasional Teknoin* **B1-B6**.
- [13] Triyono A 2007 usaha peningkatan pati ubi kayu (manihot utilissima) dengan modifikasi secara enzimatik sebagai bahan untuk industri pangan *Prosiding seminar nasional* **D7-1-D7-8**.
- [14] Sutanto A I 2001 *Pemanfaatan Pati sagu sebagai bahan baku pembuatan dekstrin secara enzimatik* FATETA IPB Indonesia.
- [15] SNI 2011 SNI **3451-2011** *Tapioka*.