DESIGN OF FUZZY LOGIC CONTROLLER FOR STARCH MODIFICATION PROCESS

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Abstract

Starch is one of the utmost broadly circulated ingredients in flora, occurring in utmost plant life. Native starch from tapioca plant exhibits limited application due to low shear stress resistance, thermal decomposition, high viscosity, poor stability. To overcome the desirable functional properties and its limitations, native starches are modified by physical, chemical, enzymatic and genetic modifications. Presently in industries chemical modification method is most commonly used for starch modification process to meet the growing population demand of the developing countries. Currently chemical modification done through manual addition of different proposition of chemicals to the native starch obtained from the raw material according to the industrial standard requirements. Manual addition of chemicals is unsafe for food processing industry, time-consuming, require skilled operators and produce chemical by products. The proposed work involves design of fuzzy logic controller for oxidized modified starch manufacturing process with proper proposition mixing of the chemicals with the native starch according to the industrial standard requirements. Here fuzzy logic mamdani model was designed to extract the exact proposition of chemicals Sodium Hydroxide (NaOH), Hydrochloric Acid (HCl) and Sodium Hypochlorite (NaClO) necessary to mix with native starch to manufacture oxidized starch. According to the variation of native starch properties as per the raw material available, the optimize level of chemical ratio to be added with the native starch for manufacturing process of oxidized starch is determined from fuzzy logic model with quality and safety measures.

Keywords: *Starch Modification, Oxidized Starch, Fuzzy Logic Controller*

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1. INTRODUCTION

1.1 Native Starch and Starch Modification

Native Starch prepared from raw materials like potatoes, corn, wheat, tapioca etc., through several starch preparation steps like washing, rasping, extraction, refining and drying has low shear stress resistance, thermal decomposition, high viscosity, poor stability. In order to meet the growing population demand, it is necessary to convert the available native starch into modified starch. Starch Modification is the process of enriching the properties of native starch through physical, enzymatic, chemical modifications or combination of these methods to meet the demands of population growth rate through industrial production. Modified starches are used as raw material in various industries like paper industry, textile industry, construction industry, food industry, chemical industry, etc. The manufacturing of modified starches for various industries are named as oxidized starch, white dextrin starch, yellow dextrin starch, etc.

1.2 Oxidized Starch

Oxidized starch is one of the modified starches produced by reaction of native starch with oxidizing agent under controlled temperature and pH. Several oxidizing agents have been used however, hypochlorite is the utmost mutual chemical used for manufacturing oxidized starch in an industrial scale. During the course of reaction, several reactions occur which lead to the introduction of carbonyl and carboxyl groups which degrade the starch molecules. Hence, oxidized starch exhibits low viscosity due to depolymerization and improve stability of starch dispersion.

1.3 Oxidized Starch Preparation

In industries, oxidized starch was prepared with the range of pH lies between 5.0 to 8.0 and viscosity lies between 1200 to 1800 centipoise minutes (cps min). According to Vedan Vietnam Enterprise Corp, Ltd QA Department, limit of sodium hydroxide and hydrochloric acid to be added with native starch must be less than 32% and for sodium hypochlorite it is less than 10%. According to variation in the level of pH and viscosity of the native starch, the proper proportions of chemical reagents were added with the native starch in order to manufacture required modified starch.

1.4 Application of Oxidized Starch

Oxidized starch is widely used in both food industries and nonfood industries where film development and adhesion properties are desired. It is also used in paper industries for improving quality of paper, mass and surface sizing. It provides yarn smoothing in textile industry and in construction industry for production of separation cardboard and acoustic strips.

1.5 Proposed Method

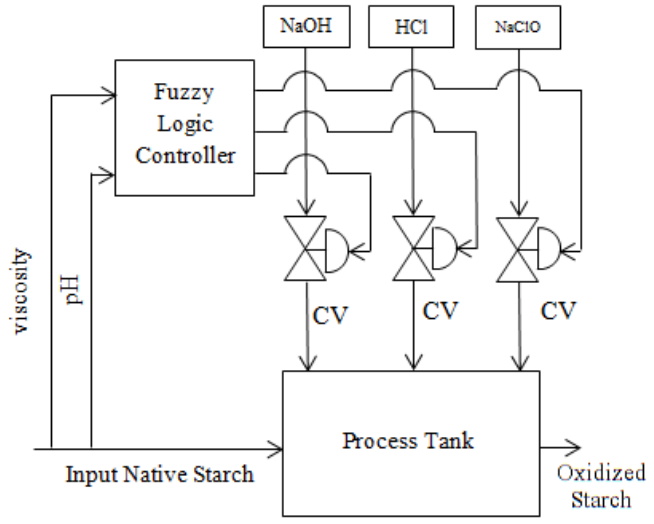

Fig -1: Block diagram of oxidized starch manufacture

Fig-1 shows the block diagram of manufacturing oxidized starch through chemical modification method. The pH and viscosity level of native starch act as input for the fuzzy logic controller. Fuzzy rules were created to open the control valve (CV) in proper proposition according to the knowledge of the starch modification process. The fuzzy logic controller controls the chemical proposition (sodium hydroxide, hydrochloric acid, and sodium hypochlorite) through control valve (CV) opening according to the variation of pH and viscosity available in the native starch. Native starch and proper proposition of chemicals are mixed in the process tank as per the fuzzy rules framed for manufacturing oxidized starch.

2. FUZZY LOGIC CONTROLLER

Fuzzy logic, which is derived from Zadeh's theory of fuzzy sets and algorithms, offers an actual means of capturing the rough, inexact nature of the physical world. It can be used to convert a linguistic control policy based on skilled knowledge for automatic control policy to control a system in the absence of an exact mathematical model. The work defined here is to investigate the suitability of fuzzy technique for control the quality of modified starch. Here Mamdani method is used to convert the fuzzy value into crisp value i.e. fuzzification and centroid method is used for defuzzification.

2.1 Fuzzy Input and Output Ranges

The level of pH and viscosity available in the native starch act as input for fuzzy logic controller and it's range is mentioned in the table -1. With respect to the table-1, pH range varies from acid high (AH), acid low (AL), neutral high (NH), neutral medium (NM), neutral low (NL), base high (BH) and base low (BL). Similarly Viscosity range varies from extra high (EH), very high (VH), high (H), medium (M), low (L), very low (VL), extra low (EL). With respect to the table-2, the output range of sodium hydroxide, hydrochloric acid, and sodium hypochlorite range varies extra high (EH), very high (VH), high (H), medium (M), low (L), very low (VL), extra low (EL) .

Table -1: Fuzzy Input Ranges

Fuzzy input linguistic variables	pH Range (5-8)	Fuzzy input linguistic variables	Viscosity Range (1200-1800) cps minutes
AH	5.0-5.5	EL	1200-1300
AL	5.0-6.0	VL	1200-1400
NL	5.5-6.5	L	1300-1500
NM	6.0-7.0	M	1400-1600
NH	6.5-7.5	H	1500-1700
BL	7.0-8.0	VH	1600-1800
BH	7.5-8.0	EH	1700-1800

Table -2: Fuzzy Output Ranges

Fuzzy output linguistic variables	NaOH Range (0-20 %)	HCl Range (0-20 %)	NaClO Range (0-10 %)
EL	0.0-0.5	0.0-0.5	0-1.66
VL	0.0-1.0	0.0-1.0	0-3.33
L	0.5- 4.5	0.5-4.5	1.66-5

M	1.0-7.6	1.0-7.6	3.33-6.66
H	4.5-10.0	4.5-10.0	5-8.33
VH	7.6-20.0	7.6-20.0	6.66-10
EH	10.0-20.0	10.0-20.0	8.33-10

3. FUZZY RULES

As per the observation made in SPAC tapioca products (India) Ltd, punachi, Erode, it is necessary to manufacture the oxidized starch in the range of pH 5.0 to 8.0 and viscosity 1200 to 1800 cps min by including necessary chemical agents which lies between 0 to 20 % for Sodium hydroxide and hydrochloric acid, whereas 0 to 10% for sodium hypochlorite. Forty nine rules were framed from the knowledge of the observed oxidized starch modification process and it is shown in table -3.

Table -3: Fuzzy Rules

viscosity	chemicals	pH						
		AH	AL	NL	NM	NH	BL	BH
EL	NaOH	EH	H	L	EL	L	EL	EL
	HCl	EL	EL	L	EL	L	H	EH
	NaClO	EL	EL	EL	EL	EL	EL	EL
VL	NaOH	EH	H	L	EL	L	EL	EL
	HCl	EL	EL	L	EL	L	H	EH
	NaClO	VL	VL	VL	VL	VL	VL	VL
L	NaOH	EH	H	L	EL	L	EL	EL
	HCl	EL	EL	L	EL	L	H	EH
	NaClO	L	L	L	L	L	L	L
M	NaOH	EH	H	L	EL	L	EL	EL
	HCl	EL	EL	L	EL	L	H	EH
	NaClO	M	M	M	M	M	M	M
H	NaOH	EH	H	L	EL	L	EL	EL
	HCl	EL	EL	L	EL	L	H	EH
	NaClO	H	H	H	H	H	H	H
VH	NaOH	EH	H	L	EL	L	EL	EL
	HCl	EL	EL	L	EL	L	H	EH
	NaClO	VH	VH	VH	VH	VH	VH	VH
EH	NaOH	EH	H	L	EL	L	EL	EL
	HCl	EL	EL	L	EL	L	H	EH
	NaClO	EH	EH	EH	EH	EH	EH	EH

4. RESULTS AND DISCUSSIONS

The input native starch range received from the raw materials and necessary oxidized starch range for manufacturing process are shown in table 4. To modify the native starch into required oxidized starch, NaClO used to maintain the viscosity whereas a combination of HCl and NaOH used to maintain the pH level. According to Fig-2, when the value of pH and viscosity of native starch were 5.341 and 1251 respectively, then the required chemical proposition for oxidized starch manufacturing process were NaOH=14.5%, HCl=0.124% and NaClO=1.45%. As per Fig-3, when the value of pH and viscosity of native starch were 6.48 and 1482 respectively, then the required chemical proposition for oxidized starch manufacturing process were NaOH=1.07%, HCl=1.07% and NaClO=4.63%. As per Fig-4, when the value of pH and viscosity of native starch were 7.2 and 1620 respectively, then the required chemical proposition for oxidized starch manufacturing process were NaOH=2.28%, HCl=5.73% and NaClO=7.11%.

Table -4 Input Native Starch Range and Required Output Starch Range

Type	pH	Viscosity(cps min)
Input Native Starch	5.0 – 8.0	1500
Output Oxidized Starch	6.0 – 7.0	70 - 100

Table -5 Required chemicals for variation of pH and viscosity available in native starch

Native starch		Proposition of chemicals required for oxidized starch modification process		
pH	viscosity	NaOH (%)	HCL (%)	NaClO (%)
5.341	1251	14.5	0.179	1.45

6.48	1482	1.07	1.07	4.63
7.2	1620	2.28	5.73	7.11

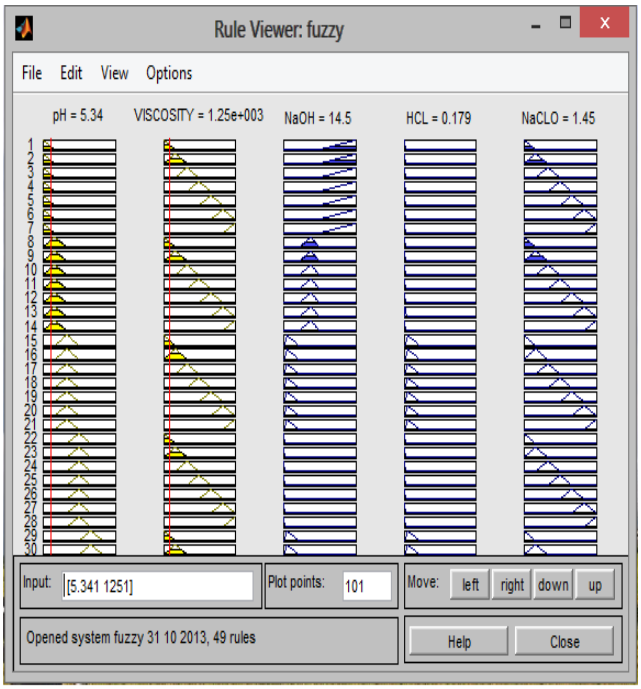

Fig -2: Rule Viewer of output 1

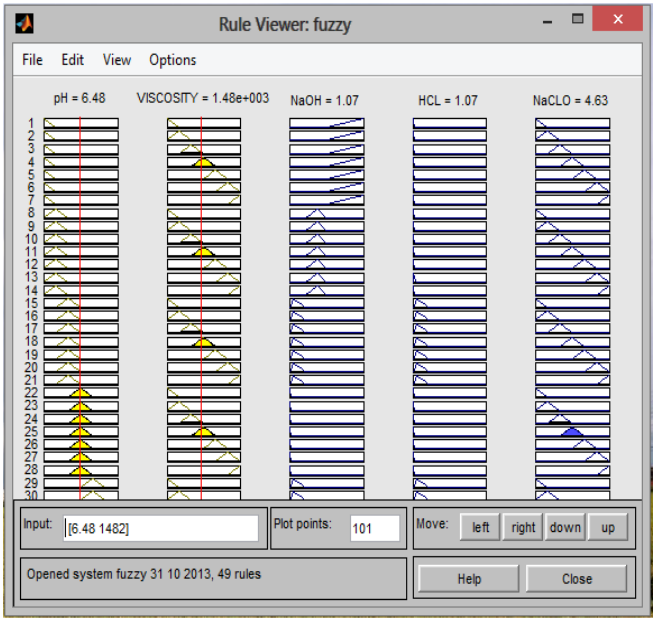

Fig -3: Rule Viewer of output 2

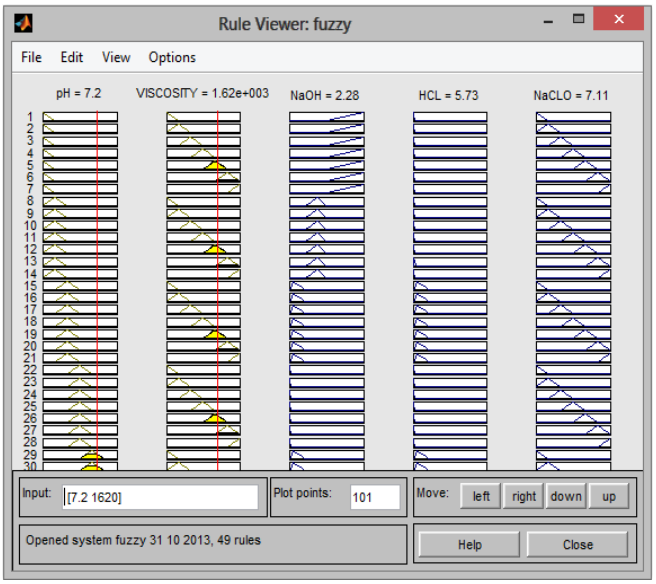

Fig -4: Rule Viewer of output 3

5. CONCLUSIONS

Today the prediction of optimized range of chemical mixing proposition is an essential issue to keep the chemical proposition under safer limits to avoid health and environmental problems in food and other industries. The proposed fuzzy logic controller predicts the accurate proposition of chemicals necessary to mix with the native starch to manufacture the modified starch (oxidized starch) with quality and safety measures. The designed fuzzy logic model for oxidized starch manufacturing process using mamdani method predict the proper proposition of Hydrochloric acid, Sodium Hydroxide, Sodium Hypochlorite to be added with the native starch. Fuzzy logic controllers does not need mathematical model and only need few rules, suitable membership function according to the knowledge of the process. In future this work can be extended for designing fuzzy logic controller for multiple modified starch production.

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