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The Application of Tapioca Cationic Starch to Wet End Paper Processing

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Abstract
The advantages of using cationic starch in the production of printing and writing papar were studied. In order to do this the physical and chemical properties of cationic starch were first analyzed. The results from the experiments showed that cationic starch can improve the strengths of printing and writing paper made from bamboo pulp more than native starch. Furthermore, drainage time of native starch was higher than cationic starch. That can decrease paper machine speed. The amount of addition of cationic starch should be 1-2%. Because tensile and burst strength were not much increase when the percent of starch samples was increased. Tear strength tended to decrease proportionally with the percent of additon of cationic starch. The burst strength of handsheets filled with high DS cationic starch was not much different compared with low DS cationic starch.

Keywords: Tapioca starch; Cationic starch; Papermaking; strength

Introduction
William (1996) stated that cationic starches are cationized with either tertiary or quaternary amine groups. The most common tertiary reagent is diethylamine ethyl chloride hydrochloride. The most common quaternary reagent is epoxy propyl trimethy ammonium chloride.

Marton (1980) stated that the degree of substitution (DS) is a measure of the average number of hydroxyl groups on each anhydroglucose unit which are derivatized by substituent groups. From the chemical structure units we can presume the maximum possible DS is three, since it has three hydroxy groups available for substitution.

Dry strength is an inherent structural property of a paper sheet which is due primarily to the development of fibre to fibre bonds during consolidation and drying of the fibre network (Roberts, 1991). William indicated that starch derivatives are the most common type of dry strength additive used in the paper industry today. Moreover, he also pointed out that from experience cationic substituents has to attach to the native starch structure in order to achieve the high retention levels required in papermaking, since native starch retention is quite low (<40%). This is undesirable from both the economic and environmental standpoints.

Dan and Tom (1991) suggested that cationic starch can be used as a dry strength additive for many types of paper such as sack paper, liner, liquid board, fine paper etc. Generally, the addition level of cationic starch in stock (pulp slurry) is about 0.5-2 percent based on the weight of dry pulp (Dan and Tom, 1991). Native starch and anionic starch have less retention and the absorption is reversible compared to cationic starch which has high retention (sometimes 100%) and irreversible bonding even in the hot water. However, he further stated that the retention of cationic starch on the fibres is effected by the charge density. The decrease in adsorption at a high DS latter is due to charge reversal of the cellulose surface with a subsequent repulsion between the cellulose surface and additional cationic starch.

Materials and methods

Materials

Bamboo pulp was kindly supplied by Teppathana paper mill Co.,Ltd. Native cassava starch and Cationic cassava starch samples e.g. AmylofaxT1100, AmylofaxT2200 and AmylofaxT3300 that have DS 0.021, 0.035 and 0.044 respectively were supplied by Siam Modified Starch Co.,Ltd.

Equipment used for making and measuring handsheets (paper samples) were supported by Pulp and Paper Unit, Department of Science service, Bangkok that were Valley beater, Disintegrator , Sheet machine, Bursting tester, Tearing tester, etc.

Methods

The degree of substitution of starch samples was measured by finding percent of nitrogen using Kjeldahl method. Calculation of DS was done by using the following formula: $DS = [(\text{Nitrogen} (\%) \div 14) \div 100] \times 162$

The pulp handsheets were be conditioned in a condition room, controlled at 65 ± 2 % RH and 27 ± 1° C at least 24 hrs. before and during testing by following Tappi T402.Moisture in Bamboo pulp and Waste paper were measured by drying in 105 ° C for 4 hr. Forming handsheets was follow Tappi T205 by soaking small pieces of pulp 30g (dry wt.) in water at least 4 hr., making volume to 2 L., disintegrating, forming handsheets and drying in ambient condition.

The pulp evaluation was done by using PFI Mill. Drainage time (Tappi T221) was measured the slowness of stock by adjusted temperature of stock at 20 ± 5° C. The other testing methods for testing pulp and handsheets such as Freeness, Grammage or Weight per unit area, Thickness or Caliper, Burst strength , Tensile strength, Tear strength and Cobb test were also follow tappi methods.

1% starch solution was added in the 5 L stock beaten at 4500 rev. of PFI mill and disintegrated at 10000 rev. of disintegrator after adjusted to pH 7.5. And the stock was diluted to 20 L. (0.15% consistency) and made to 1 .2 g handsheets.

Generally, cationic starch solution concentration that is cooked is 1-4% in the paper industries, depending on the particular application and viscosity of starch. Mostly, Jet-cooker is preferred to cook starch solution under high temperature steam and shear force. Hence cooked starch in laboratory is certainly different from cooked starch in factory.

Results and Discussion
In order to determine the amount of starch to be added for handsheets, this experiment was done. Freeness was controlled at 300 ±20 mL CSF. The results are shown in the Table 1.

Table 1 Physical property of handsheets filled with native starch in different percentage.

Percent of starch	Gram. (g/m^2)	Thick. (μm)	AD (kg/m^3)	Porosity (Gurley second)	DT (sec)	Tensile Index (kN·m/kg)	Tear Index (N·m/g)	Burst Index (kPa·m/g)
0	62.3	86.4	721	43.4	7.05	57.9	8.30	3.50
2	64.1	92.6	692	32.9	7.70	60.7	8.25	3.85
4	65.8	89.8	733	48.2	7.93	63.8	7.51	4.12
6	66.6	90.4	737	39.3	8.69	66.1	7.24	4.13
8	68.6	94.8	724	33.0	9.80	65.0	7.57	4.05

Note: AD - Apparent Density; Rev. - Revolution
DT - Drainage Time; Thick. - Thickness
Gram - Grammage

This experiment was done without the addition of the other chemicals in order to mimic the system in the factory such as filler or retention aid etc. Since the determination of the efficiencies of starches to improve the strengths in paper is the main objective.

From the data listed in Table 1, Drainage time increased with the increasing amount of starch addition. This is not satisfactory for papermaking due to longer time required for processing. Apparent density at any percent of starch are almost equal , on the other hand , porosity does not follow any tried. When porosity is increased , it means air penetrate through the handsheet is difficult or handsheet has less pores. This may implies that native starch can be efficiently retained on the paper. Burst index with 4% starch addition is increased by 17.7% compared with control (0% starch addition). The other indices did not much increased when native starch amounts were increased. So that native starch should be added at 2-4% for saving starch cost and reducing the excess starch in the effluent ,when native starch is in excess.

Table 2 Physical properties of handsheets filled with cationic starch, DS 0.021, in different percentage.

Percent of starch	Gram. (g/m^2)	Thick. (μm)	AD (kg/m^3)	Porosity (Gurley second)	DT (sec)	Tensile Index (kN·m/kg)	Tear Index (N·m/g)	Burst Index (kPa·m/g)
0	62.3	86.4	721	43.4	7.05	57.9	8.30	3.50
1	67.6	94.8	713	32.0	7.22	62.7	7.97	3.92
2	66.3	91.2	727	46.0	7.82	65.8	7.45	4.40
3	65.4	91.2	717	35.2	8.35	65.0	7.31	3.90
4	67.9	96	707	24.5	9.50	65.0	7.85	4.37

The strenghs of handsheets filled with cationic starch (DS 0.021) were more than handsheets filled with native starch. From table 2, there was 25.7% increase in the burst index and the increased porosity with addition of 2% cationic starch (DS 0.021) compared with control. This experiment proved that the higher addition (more than 1-2%) of cationic starch at low degree of substitution does not improve strength of paper at all.

Table 3 Physical properties of handsheets filled with cationic starch, DS 0.035, in different percentage.

Percent of starch	Gram. (g/m^2)	Thick. (μm)	AD (kg/m^3)	Porosity (Gurley second)	DT (sec)	Tensile Index (kN·m/kg	Tear Index (N·m/g)	Burst Index (kPa·m/g)
0	62.3	86.4	721	43.4	7.05	57.9	8.30	3.50
1	68.6	98.2	699	24.7	7.49	56.7	8.78	3.86
2	64.2	90.4	710	27.6	7.51	60.4	7.85	4.17
3	63.1	88.2	715	36.3	8.95	61.8	7.58	4.23
4	66.9	94.8	706	26.8	10.6	64.1	7.65	4.44

From table 3, The 19.1% increase in the burst index and low drainage time on 2% addition of cationic starch (DS 0.035) can be used to determine the optimal amounts to be added at this level.The high drainage time at 3-4% addition can interpreted that cationic starch may retained more than the lower addition levels. Anyhow, the strengths are not much improved when the cationic starch is further added.

Table 4 Physical property of handsheets filled with cationic starch ,DS 0.044, in different percentage.

Percent of starch	Gram. (g/m^2)	Thick. (μm)	AD (kg/m^3)	Porosity (Gurley second)	DT (sec)	Tensile Index (kN·m/kg	Tear Index (N·m/g)	Burst Index (kPa·m/g)
0	62.3	86.4	721	43.4	7.05	57.9	8.30	3.50
1	66.8	97	689	33.9	9.33	60.3	8.77	3.91
2	67.9	98	693	21.7	9.68	62.3	8.63	3.93
3	58.4	82.6	707	13.8	8.68	-	7.45	3.70
4	58.4	80.6	725	22.8	9.45	-	6.88	4.11

When cationic starch (DS 0.044) was added in the stock, the 11.7% increased in the burst index at 1% addition and burst index are not much improved in other level of addition. Furthermore, the high porosity (33.9 Gurley second) can be used to monitor that cationic starch could retain on the handsheets efficiently. Thus cationic starch of high DS should be added at 1-2% in the pulp slurry.

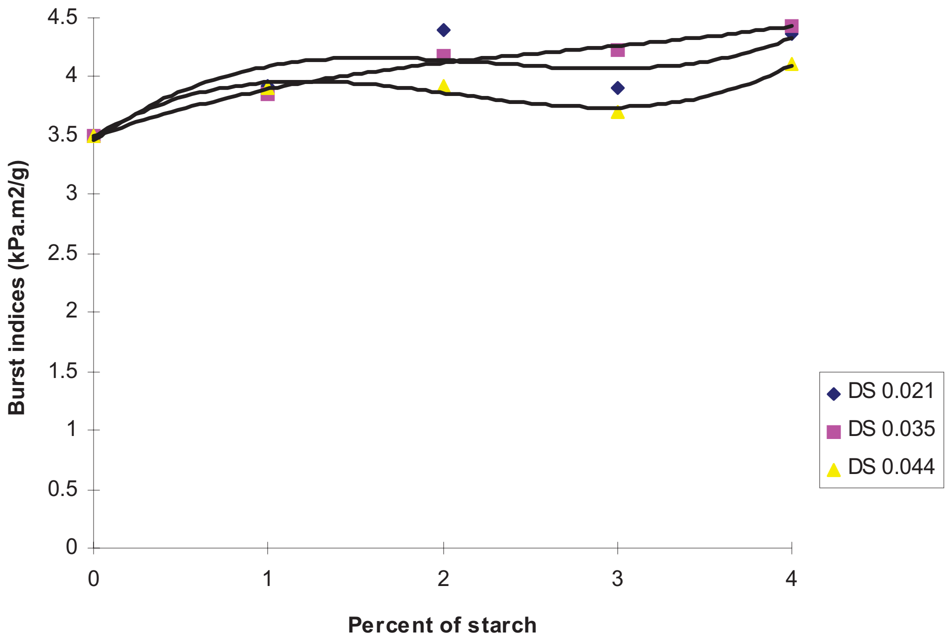

Figure 1 Burst index of handsheets filled with different percent and DS of cationic starch

Fig. 1 and the previous tables indicate that only 1-2% of the starch with DS 0.021 to 0.044 gave higher burst index. All of three types of starch gave almost the same increase. Also, if high starch concentration (3%) was used the burst index actually decreased. So at 1-2% of any type of DS is recommended to be used in these conditions. However, in commercial point of view, the cheapest one should be used. That is cationic starch at low DS.

Conclusion

Excess addition of starches does not improve the burst and tensile strengths of handsheet. And tear strengths are prone to decrease. The results indicate that 1-2% starch are optimal for papermaking.When DS of cationic starch was increased, the burst index of paper does not change much. Furthermore, when cationic starch, high DS, was added in higher percentages, the burst index decreased.

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