Gelatinization of starch and surface sizing

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ABSTRACT

A suitable surface sizing technique of of paper, adoptable in laboratory, has been standardized. Based on this method, surface sizing on creamwove paper has been carried out using native starch. The effect of varying starch concentration (10-30%) and temperature of pretreatment (70-90°C) on surface sizing properties has been studied. The results have been discussed corroborating the basic phenomena of starch occuring on thermal treatment. The degree of gelatinization has been quantified through a simple dispersibility test in the temperature range of 35-90°C. Retrogradation of starch has been determined by viscosity measurement. The surface sizing properties have been discussed based on wax pick-up along with starch pick and porosity parameters.

Introduction :

Though use of starch in paper manufacturing is known since more than a century, the fundamentals governing augmentation in strength properties of paper with starch, are yet to be understood[1] (1). On the other hand, both applications and varieties of starch have been increasing day by day (2,3), Its applications in paper manufacturing are for :

- higher filler retention
- better dry strength
- Improved surface sizing, and
- enhancement in coating properties.

The varieties of starch known are :

- cationic
- anionic
- amphoteric
- oxidised, and
- other chemically modified.

A large number of organic and inorganic additives are also incorporated with starch for improvement in various properties. The authors recently found spectacular improvement in surface sizing property of paper on addition of a small amount of an inorganic chemical (4).

However, all the progresses in applied science of starch, have not been corroborated by ample fundamental studies, It is felt that the basic mechanisms underlining strength development, can be explained based on :

- structural
- physical, and
- surface properties

of starch. This part of the paper is meant to focus on the structural and physical modifications occuring on starch during heat treatment. Though not very originals, the two experimental methods devised; surface sizing of paper and measurement of % gelatinization in starch, are also dealt in this paper. No

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such studies appeared to have been made previously at least with native starch. The results are vital for starch kitchen in the paper manufacturing.

Experimental :

The surface sizing was carried out on creamwove paper. The cooking experiment of starch was carried out in a glass beaker put in a thermostat controlled water bath. The heating is done with stirring by a mechanical stirrer. The temperature was checked by a thermometer.

The dispersibility test (5) was carried out by transferring the preheated starch into a graduated cylinder and then noting down the volume settled over night. The percentage of dispersed phase was calculated as follows :

$$D = \frac{V_1}{V} \times 100$$

where D = Percentage dispersion

V_1 = Volume settled

V = Total volume taken.

The viscosity measurement was carried out in a Brookfield viscometer.

The paper was surface sized manually. The process has been standardised in the laboratory after conducting many experiments. The porosity was measured by Bendtsen porosity meter. The surface strength was tested by Dennision waxes.

Standardisation of methods :

Surface sizing was done in the laboratory manually as described below. Two methods were tried

a) Single roll method, and

b) Double roll method.

Single roll method (Fig. 1)

A rectangular wooden piece (30 X 45 cm) was taken and a rubber mat of same size and of uniform thickness (2.5mm) was pasted on it. The paper sheet to be sized was placed on the rubber mat. A straight

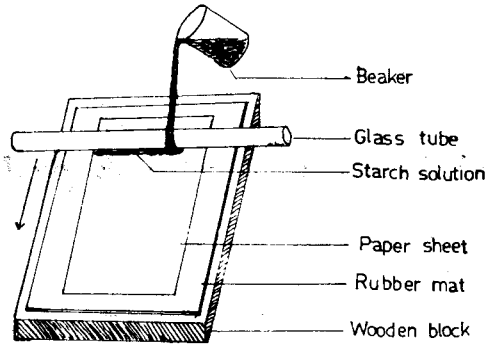


Fig. 1 : Single roll method of surface sizing

smooth glass tube of uniform diameter (1.0-1.5cm) was put at one end of the sheet. Starch solution was poured at the edge of the glass tube and immediately, the glass tube was made to slip over the paper surface with little pressure. The paper sheet was then hanged for air drying.

Double roll method (Fig.2)

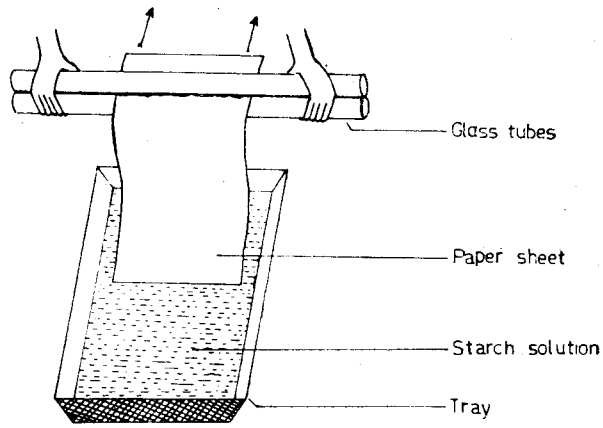


Fig. 2 : Double roll method of surface sizing.

The starch solution was taken in a tray where the paper sheet to be sized, was dipped. By lifting one end of the sheet, it was introduced in between two glass tubes. One person was to hold the two glass tubes with both the hands by applying very little pressure and another person was to pull the paper sheet in between two glass tubes. Then the paper was hanged for air drying.

By performing 5 sets of experiments, it was found that Double roll method is superior to the single roll method. The main factor considered was the distribution of starch over the paper surface. The uniform distribution was checked through porosity measurement.

In order to check the reproducibility of porosity and wax pick-up values, surface sizing was conducted on 5 sets of paper. The deviation in the base paper for porosity was 50 ml/min which went up to 70 ml/min in first method and 35 ml/min in the second method. Thus, the reproducibility was better in the paper sheets surface sized by the second method. The wax pick-up values obtained on the surface sized paper by both the methods also indicated thst the reproducibility was better in the double roll method than in single roll method.

All the experiments were therefore conducted following to the second method. This technique gives a sizing effect under pressure and therefore appears quite scientific compared to the first method.

Surface sizing was tried in the laboratory air-knife coater also, but the starch pick-up was found to be quite high. When the starch concentration was diluted to 3%, the liquid is blown away by the air pressure of the equipment.

Results and discussion :

The various mechanisms underlying the transformation of starch during (6,7) thermal treatment may first be clarified to have a better understanding namely:

Swelling
Dispersion
Gelatinization
Emulsification, and Retrogradation.

The above phenomena are overlapping and closely inter-related. When heat treatment is commenced, the starch granules swell and represent ramified structures in water leading to better dispersion (2). The gelatinisation mechanism progresses and the phases culminate to emulsification stage. On cooling, the gels retrogerad irreversibly. The stages for varying phenomena are schematised in Fig. 3.

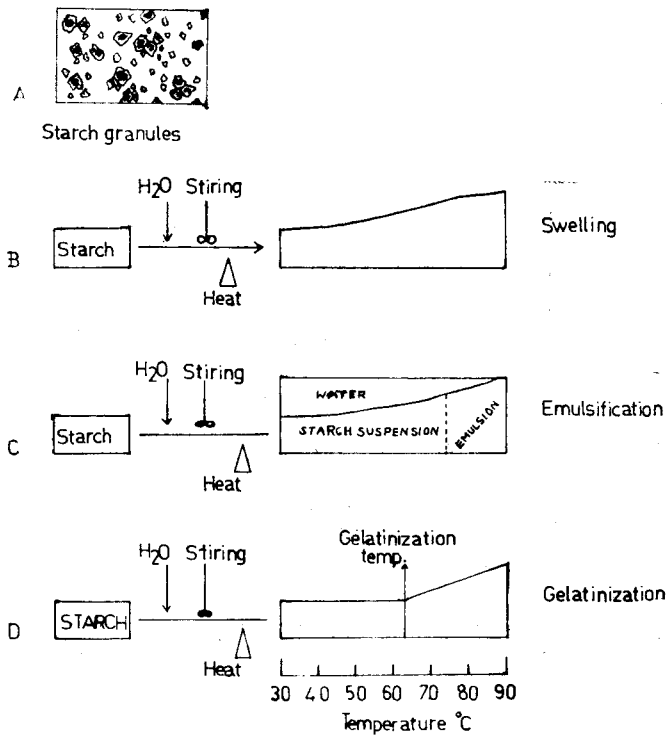


FIG 3

Fig. 3 : Phenomena occuring on starch during cooking :

A. Microscopic view of starch granules before water addition and heat treatment.
B. Swelling phenomenon shown to be taking place after 45-50 °C gradually; optimum value attained at 80-85°C.
C. Emulsification commences on addition of water at room temperature with immiscibility; slowly the immiscibility disappear on heat treatment; optimum value attained at 85–90°C-

In order for the surface sizing to be very effective, maximum dispersion with optimum gelatinizatian and emulsification is required (6). The emulsification study was carried out at cooking temperatures of 35-90°C which is shown in Fig. 4. At temperature $\geqslant$ 70°C, the dispersibility achieves to highest degree. The starch concentration was maintained at 10% with cooking time of 15 minutes in these experiments. The abrupt change in viscosity values at $\sim$ 85°C shows emulsification to be taking place at this temperature (Fig.5).

If the starch is allowed to cool after heating to 90°C, it retrogrades as represented by increase in viscosity values Fig. 6. Retrogradation effect can have serious repercussions in the mill on paper quality.

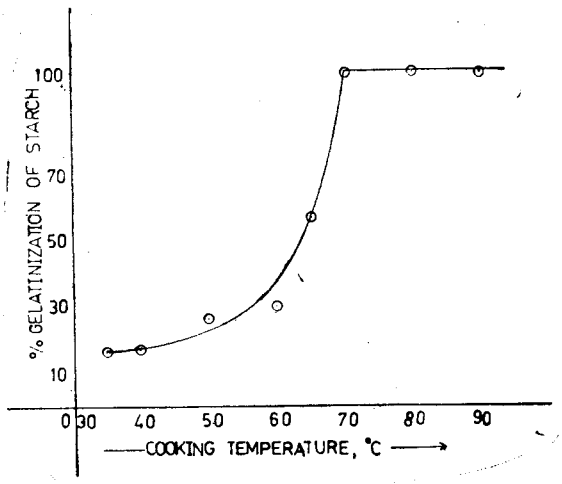


Fig. 4 : Gelatinization Vs cooking temperature.

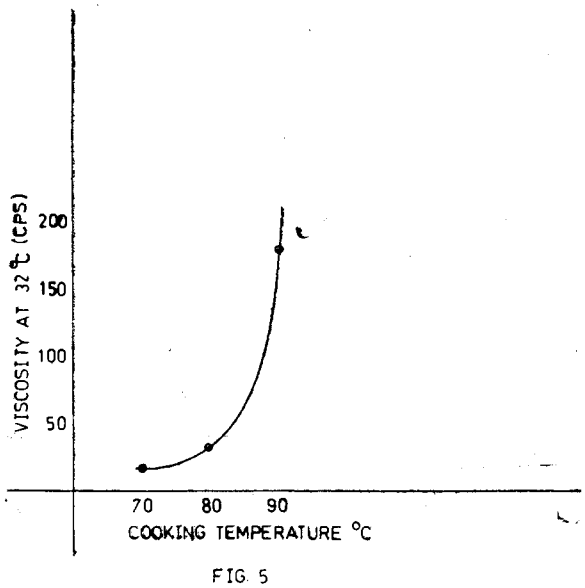


Fig. 5 : Viscosity Vs Cooking temperature.

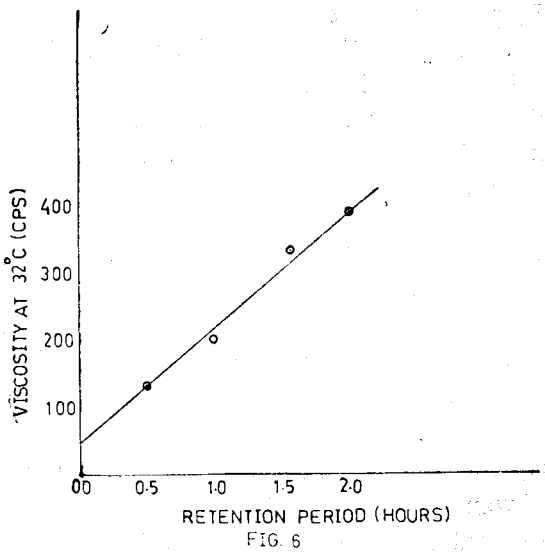


Fig. 6 : Viscosity Vs retention period.

The viscosity value decreases with increase in starch concentration when heated to 90°C. At 10% of concentration the viscosity was (Fig. 7) 235 cps while at 30% concentration it dropped to 25 cps. This is because of restriction in swelling of the strach granules imposed at increased concentration. Gelatinization occurs with introduction of one water molecule in between two glucose units of the starch molecule,

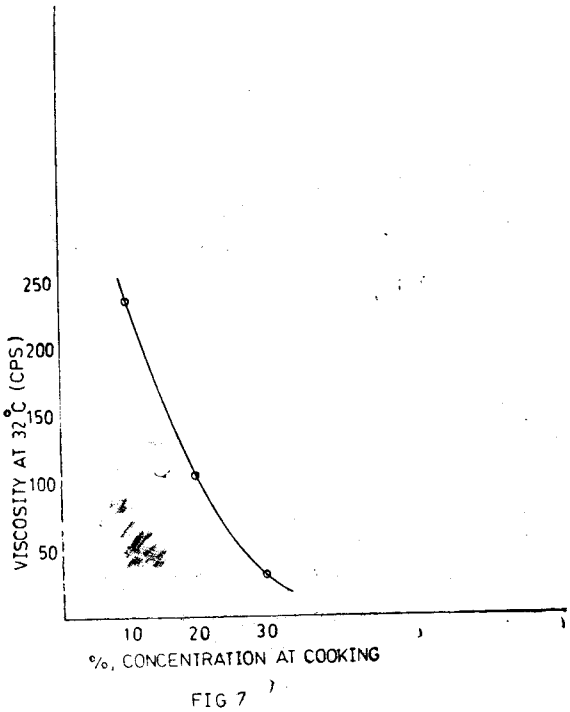
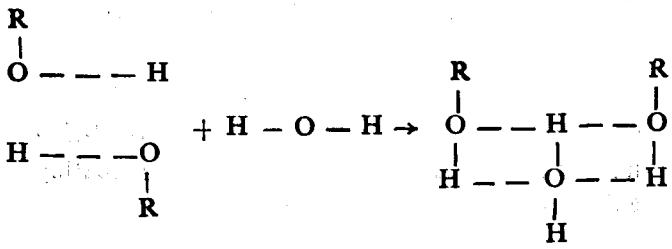


Fig. 7 : Viscosity Vs concentration of starch.

which can be represented as follows (7) :



When the system prevailing is water-deficient or lacks in adequacy of space, the swelling process of the granules is hampered and consequently the gelatinization can not take place effectively. This is represented by lowering of the viscosity values.

Table-1 shows the paper properties after surface sizing with different concentration of starch. The starch pick-up value increases from 3 to 5.2% as the concentration of starch increases from 10 to 30%. The porosity values were, however, found to be increasing with rise in starch concentration; it is 165 ml/min at 10% starch concentration instead of 230 ml/min at 30% concentration. The wax pick-up value of paper surface sized with 10% concentration of starch was higher than at 20 and 30% starch concentration. The emulsion with 10% of starch concentration is thus quite suitable for surface sizing Temperature suitable for starch cooking is 90°C, as it can be seen from results in Table-2. The wax pick-up values at 70 and 80°C are inferior to that cooked at 90°C. The porosity values are also high in paper cooked at 70 and 80°C.

TABLE—1

Surface properties of starch with different concentrations

Poroperties		10%	20%	30%
Starch pick,	%	3.0	4.8	5 2
Prosity (Bendtsen)	ml/min	165	210	230
Wax pick	No.	14	13	13

TABLE—2

Surface properties of paper sized with starch heated to various temperatures

Properties		70°C	80°C	90°C
Starch pick	%	2.7	2.6	3.0
Porosity (Bendtsen)	ml/min	270	250	165
Wax pick,	No.	13	13	14

Conclusion :

The starch concentration most suitable for surface sizing is 10% and temperature 90-98°C. This system is attained with optimum swelling of starch granules leading to accelerated gelatinizing mechanism and resulting in highest degree of emulsification.

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