Starch and Starch Products for Wet End Application

PREFACE

TAPPI PRESS books review the state of the art in a specific field in papermaking. The use of starch and starch products in surface sizing and as a coating binder has been covered in a series of TAPPI monographs; the most recent one published in 2001. However, there has not yet been a treatise that addresses issues in the preparation and application of starch and starch products for use in the wet stages of the papermaking process. This publication intends to close this gap and serve as a complement to the previous publications on the surface application of starch.

TAPPI monographs serve as guides to operators, engineers, and other professionals in production, research, and product development. In recent years, there have been wide ranging changes in the operation of the wet end of the paper machine. New procedures in starch utilization, many of them in conjunction with fine pigments and synthetic polymers, made substantial increases in production speed and product quality possible. Successful management of high speed papermaking in this new technical era requires detailed understanding of polymer properties, the importance of charge, and the interaction of furnish components.

This publication covers a wide range of subjects in starch utilization, ranging from the preparation of specific starch products to their use in papermaking for flocculation, retention, drainage, strength, and sizing control. Environmental issues in the use of starch and analytical procedures for starch analysis and charge characterization are also addressed. All chapters were appended with references to the relevant scientific and technical literature and with special emphasis on publications during the last 20 years when many of the new procedures for starch utilization at the wet end were first commercialized. The most recent patent literature was also referenced. An attempt was made to balance the text to make it informative and valuable to both operating personnel in the paper mills and their research and development staff. Furthermore, this monograph might be beneficial to personnel in the starch industry, various suppliers to the paper industry, and in the teaching of students for careers for and in conjunction with the paper industry. The varied background of anticipated readers of this book has made it advisable to repeat certain introductory and general arguments in chapters on different modes of starch application. This practice will allow to study the subjects on their own without need to refer to introductory chapters, while also emphasizing the broad action spectrum of starch use for different application targets.

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It is my sincere hope that this monograph will serve the paper industry well as a source of information and as a guide to further advancement in the use of starch products for the cost effective production of superior grades of paper and paperboard.

Hans W. Maurer

TABLE OF CONTENTS

USE OF STARCH IN THE MANUFACTURE OF PAPER

Starch is an important additive in the manufacture of most grades of paper and paperboard. The consumption of starch in the papermaking process and during subsequent conversion operations ranks third by weight after cellulose fiber and mineral pigments. The global paper industry consumes about 5 million tons/year of starch. For the total world paper and paperboard production of about 330 million tons/year, the quantity of added starch represents about 1.5% starch by weight across all grades of paper and paperboard (1).

Starch utilized by the US paper industry is primarily derived from corn. Additional sources of starch are potatoes and wheat. The characteristic shapes of the major commercial starches are illustrated in **Figure 1.1**. For most uses in papermaking, starch is chemically modified by either the starch supplier or on-site, which enhances performance for specific applications. Only in corrugating and laminating is a large share of unmodified starch used.

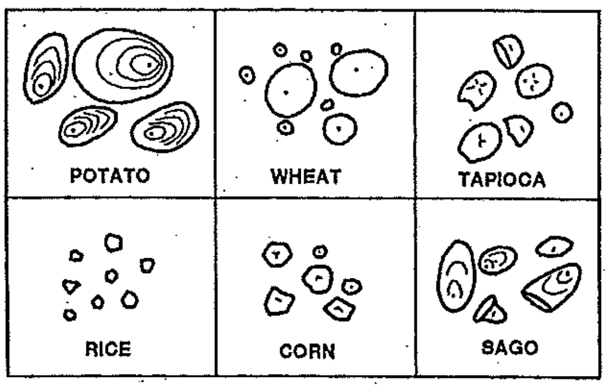

Figure 1.1 Characteristic granular shapes of commercial starches

Annual consumption of industrial starch in the US for paper and paperboard production during the 1990's exceeded 2.5 billion pounds, of which about 70% were utilized in chemically modified form. Another 1 billion pounds were consumed for corrugating and laminating applications (2). In paper manufacturing, the largest share of starch is used for surface sizing (64%), followed by wet end addition (21%), use as coating binder (12%), and for spraying (3%). (2).

Starch products are required for a variety of needs in the production of paper and paperboard, such as:

- Drainage aid to enhance water removal from the papermaking stock,
- Flocculant to facilitate the formation of a uniform sheet of paper during water drainage,
- Retention aid to trap fiber fines and pigments within the paper structure,
- Bonding agent to increase the strength and printability of paper and paperboard,
- Carrier for sizing agents to control water sensitivity of paper and dimensional stability,
- Activating agent for fluorescent brightener added to paper,
- Adhesive to bond loose fibers at the dried sheet surface and to induce stiffness, raise strength, and facilitate printability,
- Binder for pigmented coatings that are applied to the finished paper to attain high levels of optical properties, smoothness, gloss, and printability,
- Adhesive for the conversion of paperboard to a multitude of packaging applications,
- Flocculant for mill effluent treatment and reduction of COD in waste water.

POLYMERIC PROPERTIES

Plants store small granules of starch in specific locations, primarily in seeds, tubers, or roots, from which the starch manufacturer removes them (2. 3. 4). Different starches are specified by their form, size, size distribution and bulk density (**Table 2.1**), the latter depending on the drying process used after separation from the plant source. Wheat starch is distinguished by a bimodal distribution of particle sizes (5).

hydrogen bonding (10, 11, 12). Both can be thermally dispersed in water (13, 14, 15).

In amylose, about 300 to 6000 α-1, 4 linked anhydroglucose units form a glucopyranos<u></u>y chain. When isolated and hydrated, the molecule twists due to entropy into the shape of a helix (16) while the closely related cellulose molecule remains straight (**Figure 2.3**).

Starch has to be dispersed in water for mo<u></u>st of its applications. Dispersion is generally

STARCH	PARTICLE SIZE µm AVERAGE	RANGE	BULK DENISTY* LB/FT³ LOOSE	PACKED
Regular corn	15	5-25	36	50
Waxy maize	12	5-25	34	51
High-amylose	15	5-40	37	52
Grain sorghum	15	5-30	...	...
Waxy grain sorghum	15	6-30	...	...
Wheat	10	2-35	38	54
Rice	5	2-10		
Potato	30	15-100	46	56
Sweet potato	12	10-25	...	...
Tapicoa	20	5-35	37	52
Sago palm	35	15-65	...	...
Banana	30	5-90	...	...
Arrowroot	25	8-50	...	...

****Bulk densities will vary. Flash-dried starches have lower bulk densities than belt-dried starches, i.e., belt-dried corn = 42 lb/ft³.***

Table 2.1 Granule size and bulk density of starches

Commercial starches are not completely neat, since some residue will remain with the starch granules after separation from their source (6) (**Table 2.2**). Starch granules are semi-crystalline, containing regions that are highly crystalline and others that are amorphous (7). Water is an integral part of the starch granule; it is also adsorbed and desorbed, depending on the prevailing relative humidity (8, 9).

At the molecular level, starch is actually a blend of two different structures, amylose and amylopectin, which are associated through

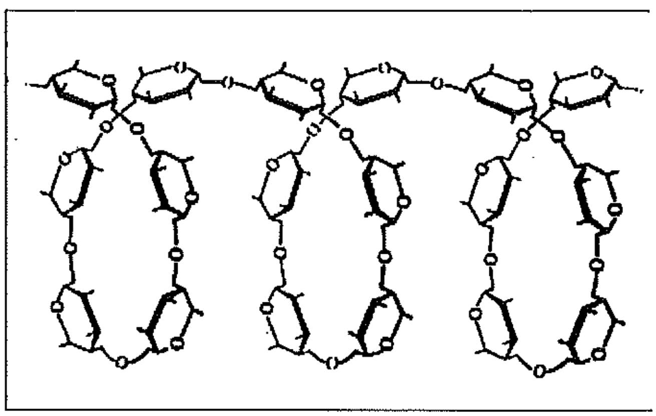

Figure 2.3 Macromolecular conformation of amylose