

Chapter 7 Starch processing

7.1 Starch Composition

7.2 Starch properties

7.3 Starch Isolation

7.4 Modified starch

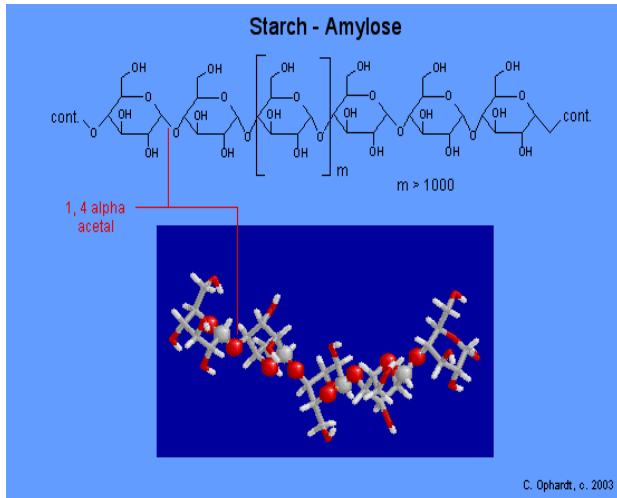
7.5 Starch hydrolysates

7.1 Starch Composition

- **Amylose**. Linear alpha-1,4 glucose chain['ælfə]. DP: 180-320, MW~10⁶. Branch approximately every 200 glucose units
- **Amylopectin**. Linear alpha-1,4 chain with an alpha-1,6 branch approximately every 20 glucose units. MW~10⁸
- **Amylose: amylopectin ~ 1:3**
 - Waxy starches all amylopectin
 - High amylose mutants up to 70% amylose

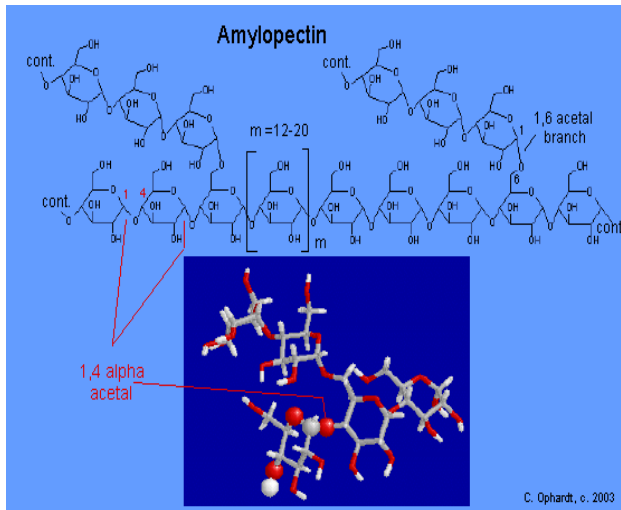
Amylose

- **Linear component of starch**
- **Contains 1,4-alpha-glucosidic bonds**
- **Molecular weight: less than 0.5 million**
- **Can form coils which will trap iodine and turn blue**



Amylopectin

- Branched component of starch
- Contains 1,4-alpha-glucosidic as well as 1,6-alpha-glucosidic bonds
- Molecular weight: 50-500 million
- Limited coiling causes purplish-red color when iodine added



Starch Granule

- **Amylopectin forms in concentric circles with amylose dispersed in between**
- **Held together by hydrogen bonds**
- **The granule swells when heated in water**

Starch Granule

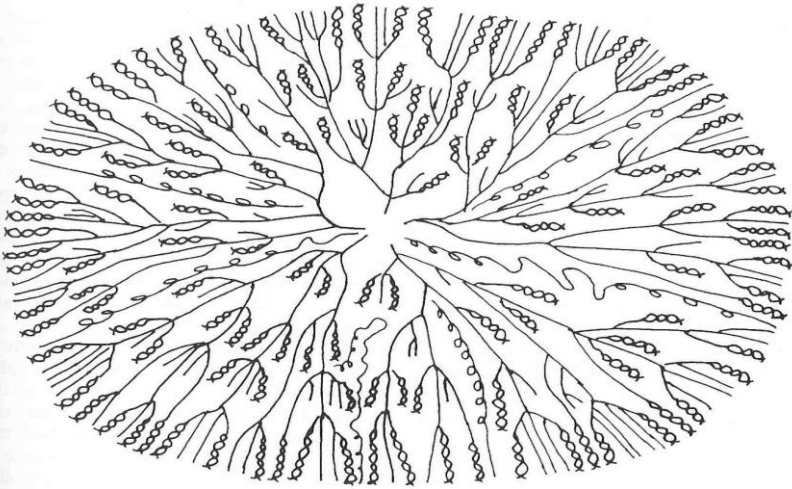
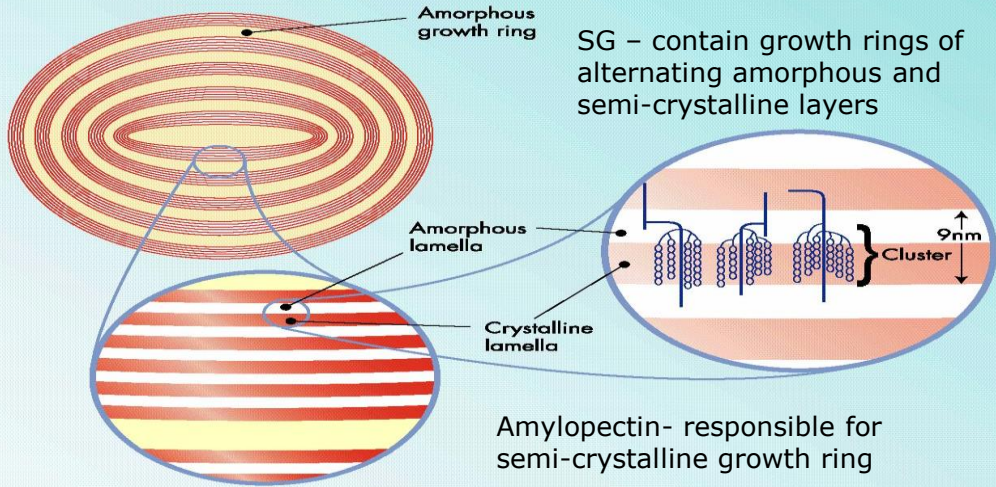
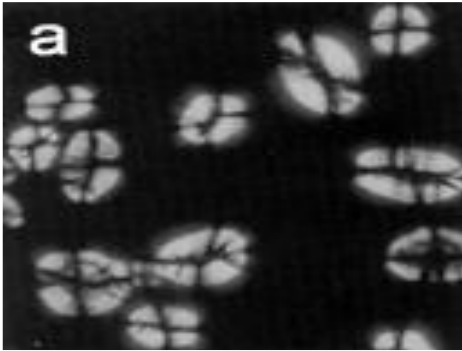


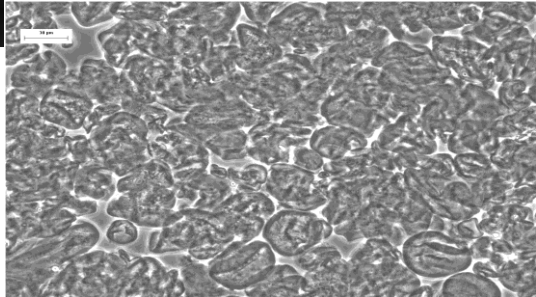
Figure 9.4 Schematic of the organization of a starch granule. (Diagram by D. R. Lineback. (Courtesy of D. R. Lineback and *Baker's Digest*, 1984, 58(2): 16.)

Starch Granules (SG)





Unheated starch granule



Heated starch granule

- 由于淀粉具有不溶于冷水和比重大于水两个基本特征，这是淀粉得以制取的根本原因。
- 由于制取淀粉的过程中需要大量用水，故有“水磨法”之称（**wet-milled**）。



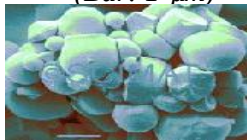
Amaranth (苋菜籽) starch
(Bar: 1 μm)



Arrowroot (竹子) starch
(Bar: 20 μm)



Buckwheat (荞麦) starch
(Bar: 5 μm)



Cassava[kə'sa:və] starch
(Bar: 10 μm)



Corn starch
(Bar: 10 μm)



Oat starch
(Bar: 5 μm)



Potato starch
(Bar: 50 μm)



Rice starch
(Bar: 2 μm)



Kidney bean starch
(Bar: 20 μm)

7.2 Starch properties

7.2.1. Gelatinization, Pasting and Gelation

- When starch is heated in water**
- Hydrogen bonds break, allowing water to enter the granule and the granule swells**
- Amylose migrates out of the granule**
- H-bonding between water and amylopectin increases**
- Reduced free water changes the viscosity of the starch mixture, thickening it**

Gelatinization and Pasting

- **“Starch gelatinisation is the collapse (disruption of molecular order) within the starch granule,**
- **manifested in irreversible changes in properties**
- **such as granular swelling, native crystalline melting, loss of birefringence and starch solubilisation.”**

Gelatinization and Pasting

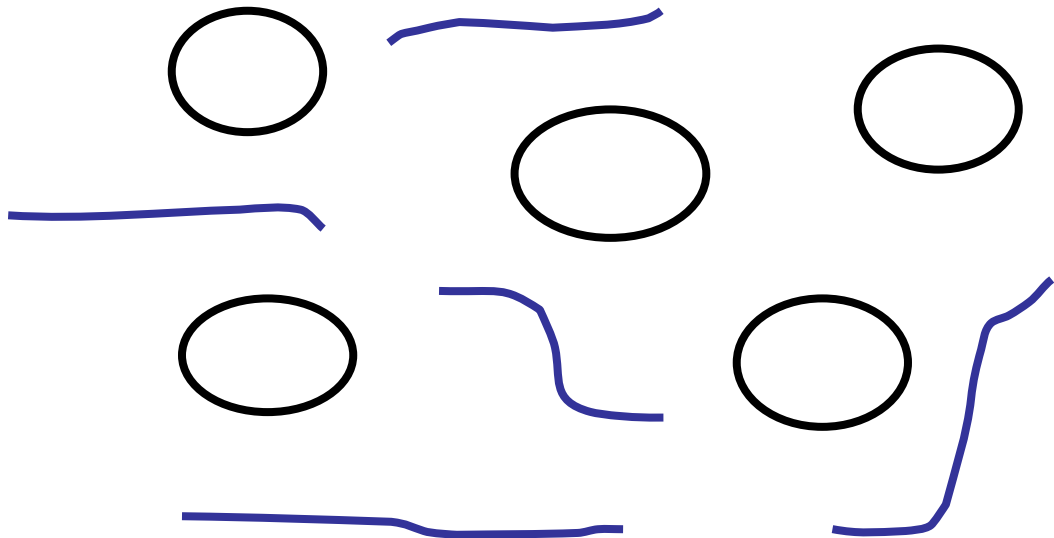
- **“Pasting is the phenomenon following gelatinisation in the dissociation of starch.**
- **It involves granular swelling, exudation 渗出 of molecular components from the granule;**
- **and eventually the total disruption of the granules.”**



**Raw, uncooked starch granules
heated in water**

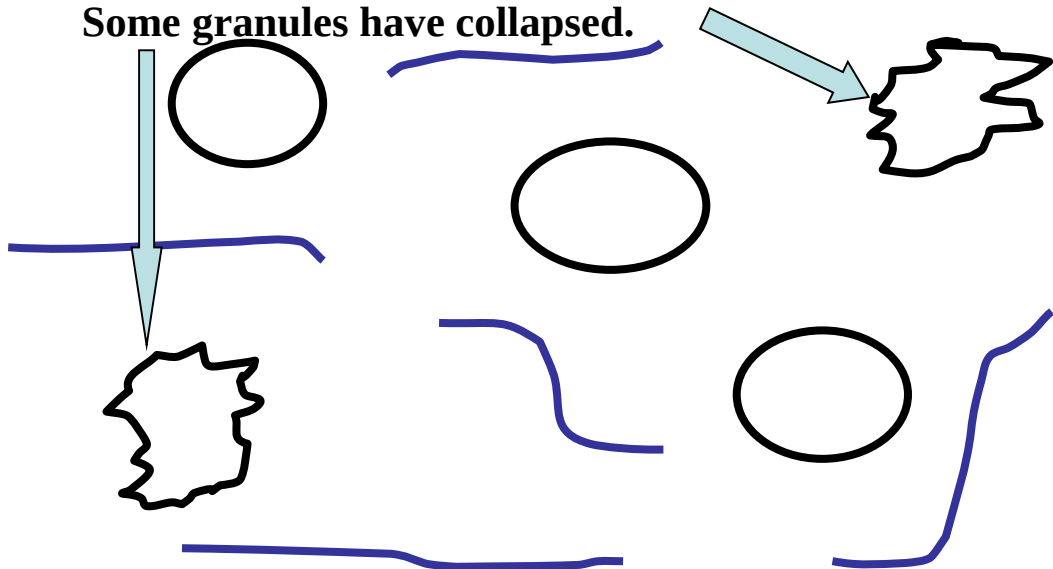


Swelling is evident

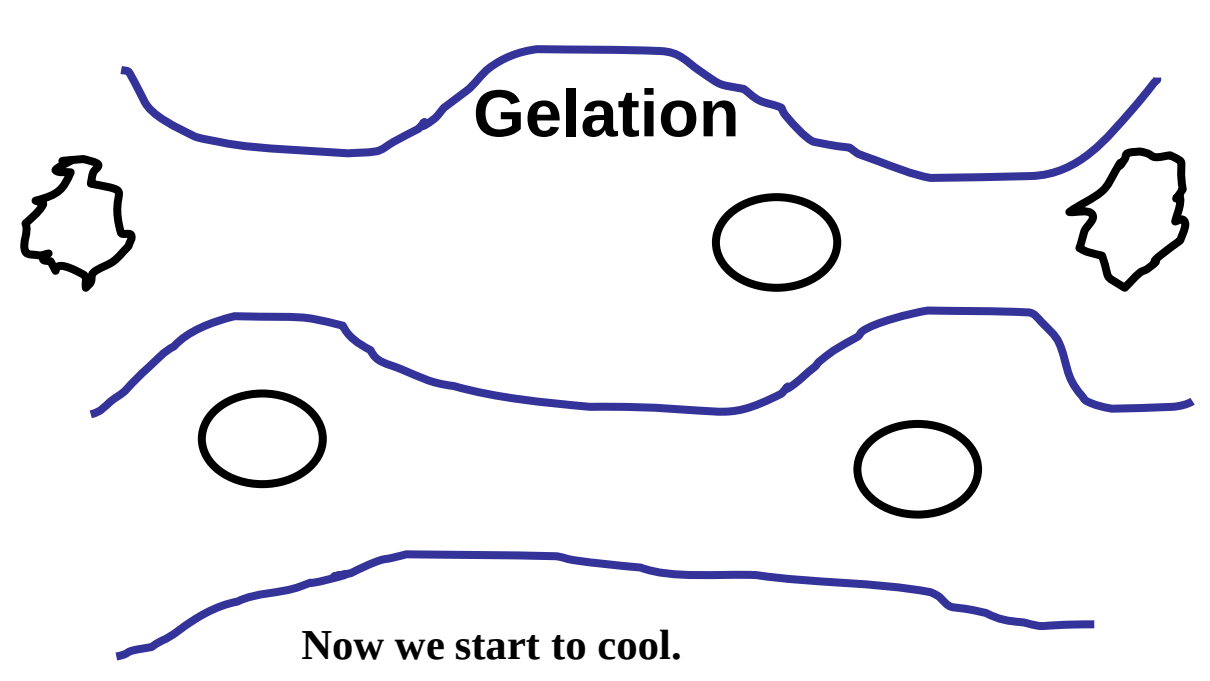


Notice loss of **amylose** from the granules

Some granules have collapsed.



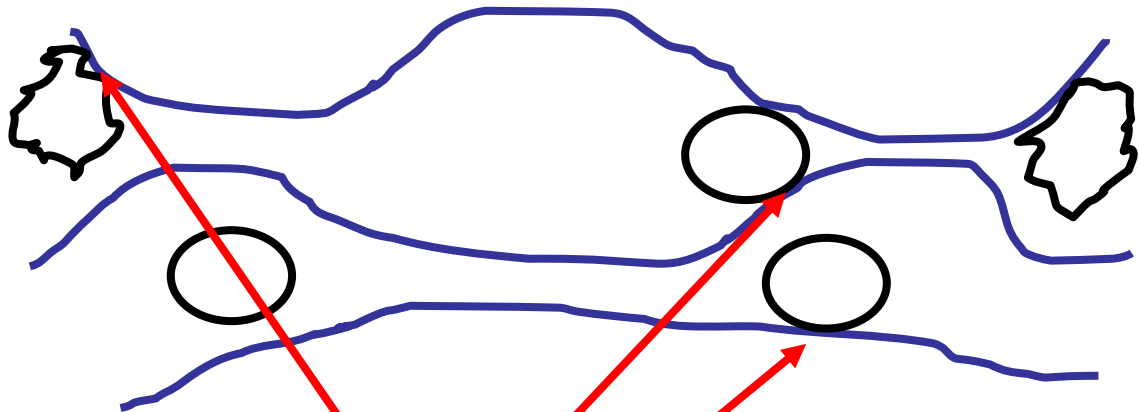
Gelatinization and pasting are complete



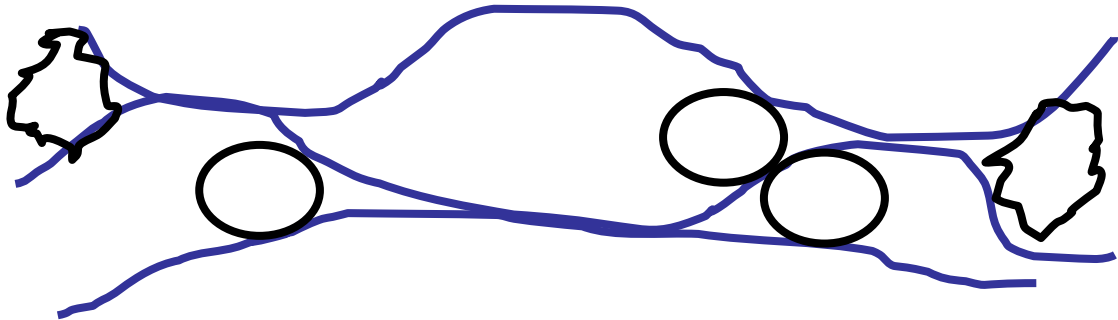
The diagram illustrates the process of gelation. It features three horizontal blue lines representing polymer chains. The top line is wavy and has the word "Gelation" written above it. The middle line is also wavy but has two black circles (representing cross-links) on it. The bottom line is relatively straight and has the text "Now we start to cool." written below it. On the far left and right, there are two irregular black outlines representing clusters or aggregates of polymer chains.

Gelation

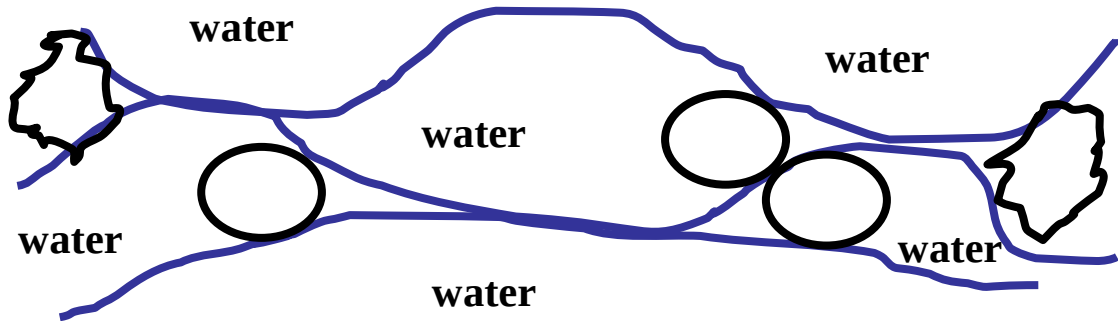
Now we start to cool.



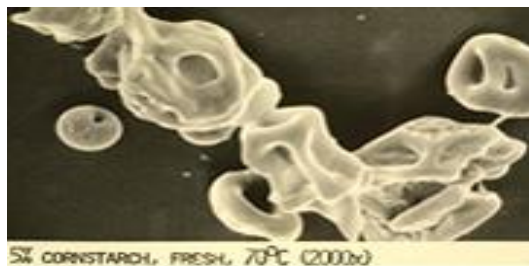
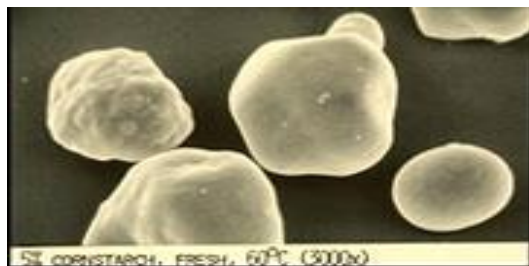
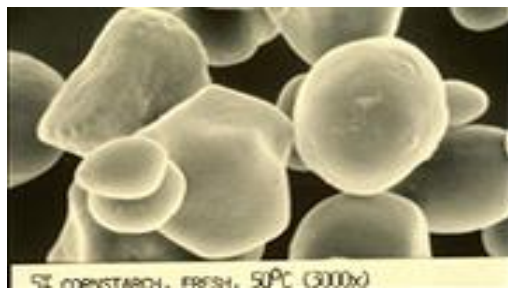
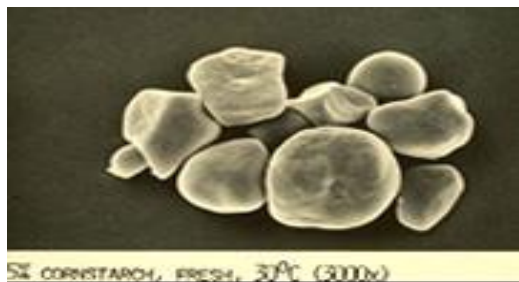
Notice areas of association. These are called **junction zones**.



This picture is not yet complete as we haven't accounted for the water in the system.

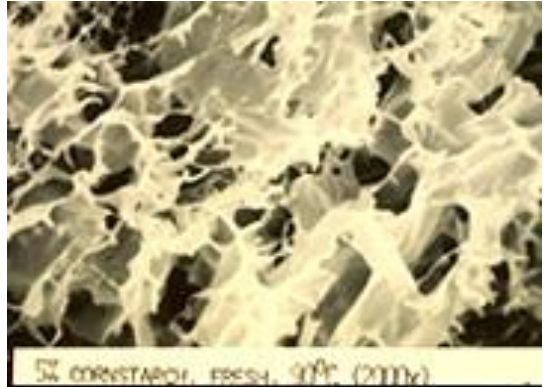


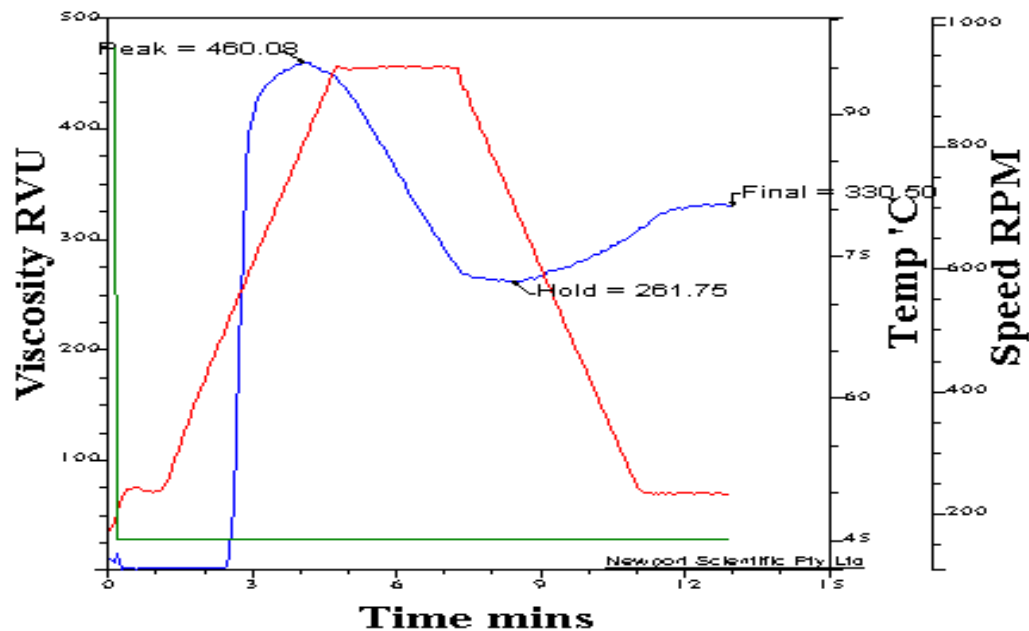
This is a starch gel



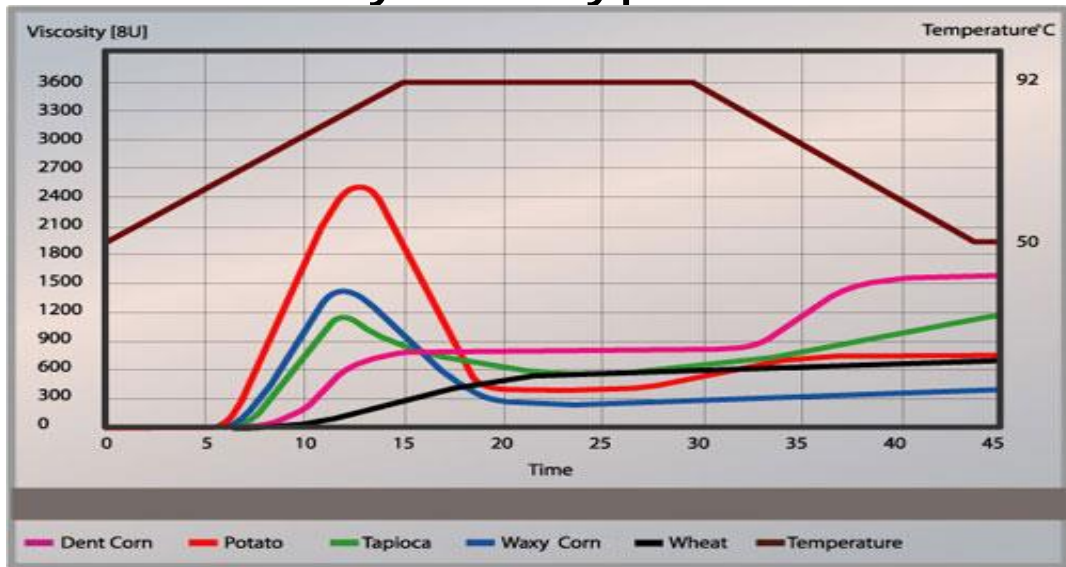
Effect of continuous heating in excess water

- Results in formation of starch paste due to:
 - further granule swelling beyond reversible point
 - additional leaching of soluble compounds
 - total disruption of granules





Viscosity and Type of Starch



Gelation

- **As a starch paste cools, a gel is formed**
- **Free amylose molecules lose energy as the temperature decreases and form hydrogen bonds**
- **The bonds create a network that holds the swelled granules in place**

Paste and gel

- **Paste**

- Granule swelling and disruption of granules produce

- **Viscous mass (paste)**

- Consisting of a continuous phase of solubilised amylose and or amylopectin and a discontinuous phase of granule remnants (granule ghosts and fragments)

Cooling of a hot-starch paste partially reassociate resulting in a viscoelastic, firm, rigid precipitate or gel, process called retrogradation.

- **Gel**
 - **continuous, 3-dimensional network of connected molecules or particles entrapping a large volume of a continuous liquid phase, much as does a sponge**
- **In many food products, the gel network consists of polymer molecules or fibrils formed from polymer molecules joined in junction zones by hydrogen bonding, hydrophobic associations, ionic cross bridges, entanglements, or covalent bonds, and the liquid phase is an aqueous solution of low-mw solutes and portions of polymer chains.**

7.2.2. Retrogradation

- Solubilised starch polymer and remaining insoluble granular fragment tend to re-associate after heating.**
- The re-associating is termed “Retrogradation”.**
- Retrogradation has been defined as follows:**

7.2.2. Retrogradation

- **“Retrogradation is a process which occurs when starch chains start to re-associate into an ordered structure.**
- **In its initial phase, two or more starch chains may form a simple junction point, which then may develop into more extensively ordered regions.**
- **Ultimately, under favourable conditions, a crystalline order appears.”**
- **Generally, amylose-containing starches show greater retrogradation.**

Factors relating to retrogradation include:

- ① Temperature 4°C**
- ② Moisture content 20-60%**
- ③ Amount of branching**
- High amylopectin starches - e.g., waxy maize shows no retrogradation when frozen**
- Hydrogen bonding between OH groups in amylose in gelatinised starches during cooling**
- Water forced out of gel structure (syneresis) & Starch insolubilized.**

Factors relating to retrogradation include:

- ④ Amylopectin also plays a role in retrogradation over time.**
- Short-term retrogradation is largely associated with amylose (which reaches a limit in 2 days), whereas long-term retrogradation is thought to involve amylopectin (reaching a limit is 40 days)**

7.3 Starch Isolation

- Starch can be extracted using various processes, depending on the plant source and end use of the starch.**
- Wet milling processing is widely used in cereal starch production.**
- The purpose of wet milling is to separate the kernel (grain) into its constituent chemical components.**
- Figure 7.1 presents the major procedures for extracting starches from cereal grains and tubers.**

7.3 Starch Isolation

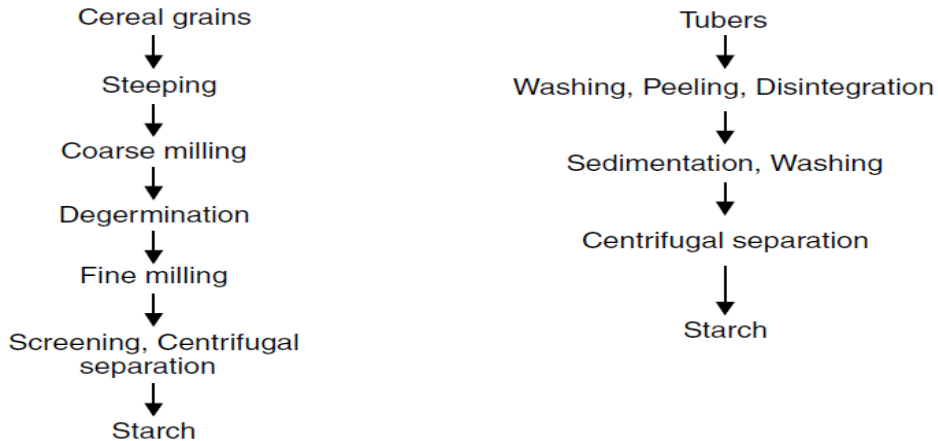


FIGURE 7.1

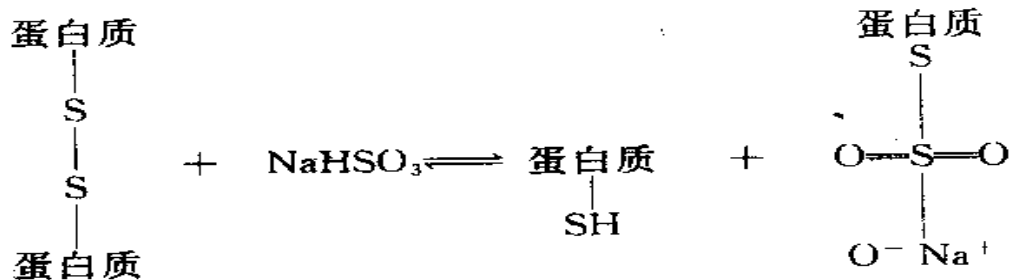
Major steps in starch isolation from cereal grains and tubers.

7.3.1 Cereal starch isolation

- As shown in the schematic, the major steps of cereal starch isolation include steeping, milling, and separation.**
- Steeping is the first critical processing step in wet milling.**
- It usually involves using an aqueous solution of sulfur dioxide and lactic acid at certain pH and temperature for certain periods of time.**
- This unit operation is carried out for about 40 hours.**

7.3.1 Cereal starch isolation

- The main purposes of the steeping process are to loosen the granules in the packed cell structure.

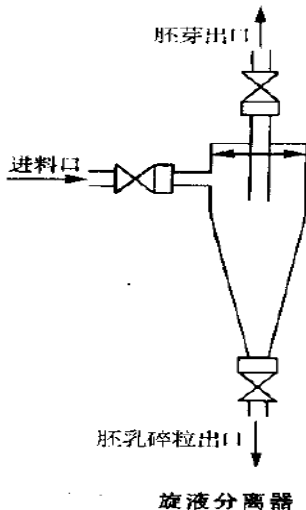


7.3.1 Cereal starch isolation

- **To isolate starch with minimum damage and maximum purity;**
- **To reduce or inhibit the activity of undesirable microorganisms.**

7.3.1 Cereal starch isolation

- After steeping, the softened grain is degerminated by coarse grinding粗磨.
- A hydroclone水力旋流器 separator is used to separate the germs which are less dense and contain high levels of oil.



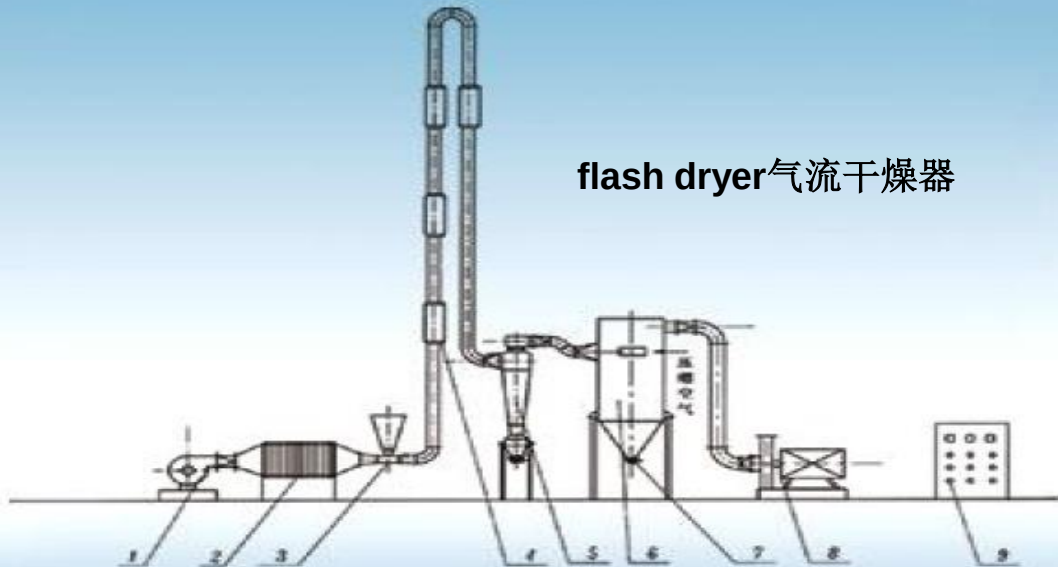
7.3.1 Cereal starch isolation

- The remaining materials are reground to liberate most of the remaining starch and other components.**
- Starch can be separated from other components by centrifugation, based on density difference between starch and other components such as protein.**

7.3.1 Cereal starch isolation

- Drying: The purified starch milk is dewatered by means of a thickening filter in order to reach a dry solid content suitable for the following drying.**
- Drying is operated by dosing the starch into the dryer at controlled temperature maintained by an air conditioning unit.**
- The dry starch is then separated by the air stream and stored and packed .**

flash dryer气流干燥器



- 1 鼓风机 2 换热器 3 螺旋加料器 4 脉冲气流干燥器
5 旋风分离器 6 高压脉冲除尘器 7 蝶阀 8 引风机 9 自控柜

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