Amylose, amylopectin, & amylase: Wheat in the RVA.

Andrew S Ross
Oregon State University

- SOME HISTORY
- INSTRUMENT BASICS
- BASIC CURVE DESCRIPTORS
- UNDERLYING PRINCIPLES
- INCREASING AQUEOUS PHASE VISCOSITY (η_0)
- AMYLOSE & AMYLOPECTIN
- RETROGRADATION / SETBACK
- AMYLASE
- OTHER SPROUT EFFECTS

Some history

It not unfrequently happens that flour of good colour, and unexceptionable chemical composition, fails to yield a dough which will rise by fermentation, and the loaf from which is sweet, solid, sodden, and adhesive. Wheat that has been badly harvested, or which in any way has been allowed to sprout, has part of the gluten changed into the form of diastase, which, like cerealin, changes starch into dextrin and sugar. The gluten of flour which has been dried at a too high temperature, and of flour which has been kept in a damp situation, is modified and acts in the same manner. If dough is made with an infusion of malt, it yields a result exactly the same as that above described.

THE

ENCYCLOPÆDIA BRITANNICA

Ninth Edition—Popular Reprint

NEW YORK

HENRY G. ALLEN AND COMPANY

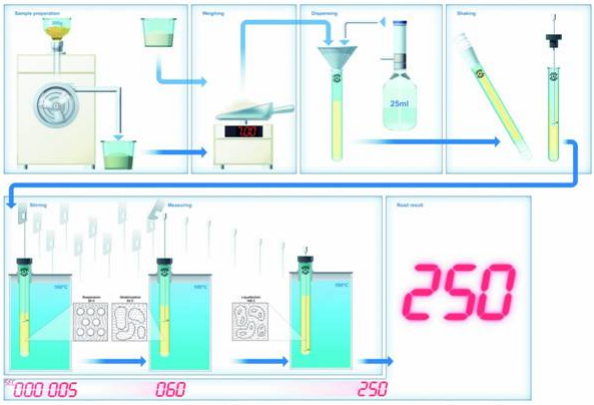
PUBLISHERS

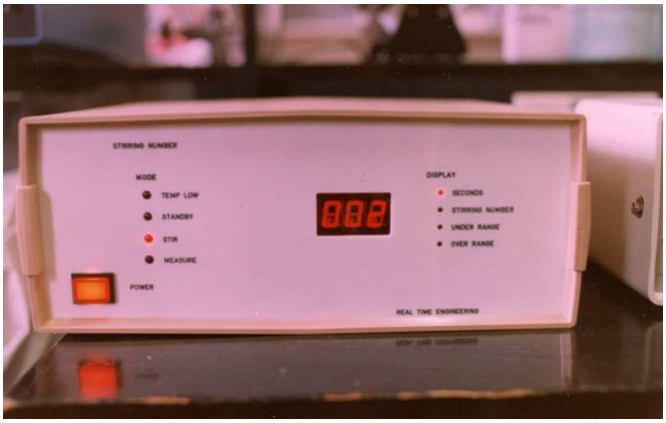
1888.

Cereal Chemistry, volume 37, 1960,
S. Hagberg: "A rapid method for determining alpha-amylase activity", pages 218-222

--

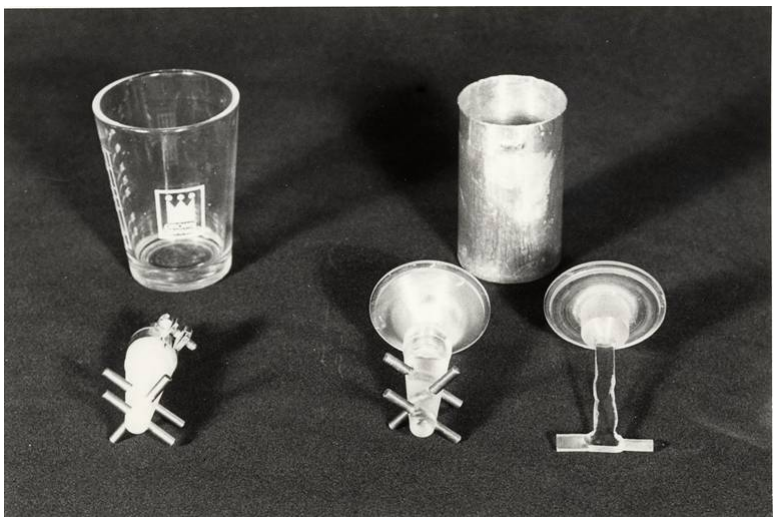
Cereal Chemistry, volume 38, 1961,
S. Hagberg: "Note on a simplified rapid method for determining alpha-amylase activity", pages 202-203





1984: The concept "gels"

Combine the rotational sensing of apparent viscosity of the amylograph with the ballistic heating attribute of Falling Number



1984-85 early paddles

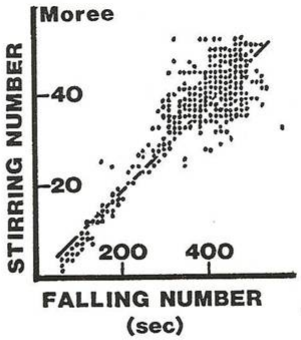


FIGURE 2. Stirring and Falling Number testing of wheat samples (listed in TABLE 1) received at Moree Sub-terminal. Points may represent more than one sample.

Ross A.S., Orth R.A., Wrigley C.W., 1987. Rapid screening for weather damaged wheat. pp 577 – 583 *In: Fourth international symposium on pre-harvest sprouting in cereals*. D.J. Mares, ed, Westview Press, Boulder Colorado, USA.

Instrument basics

2 ■ CHAPTER 1

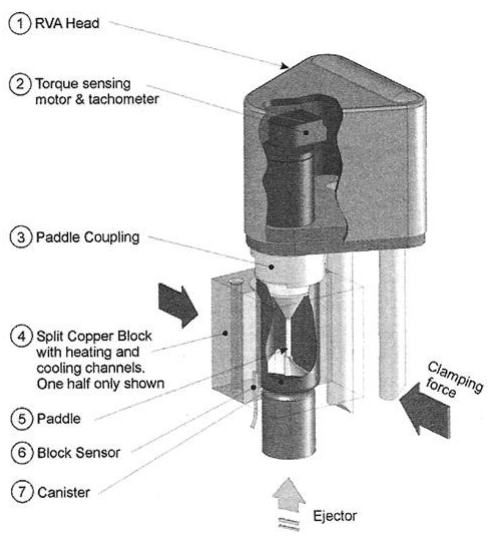
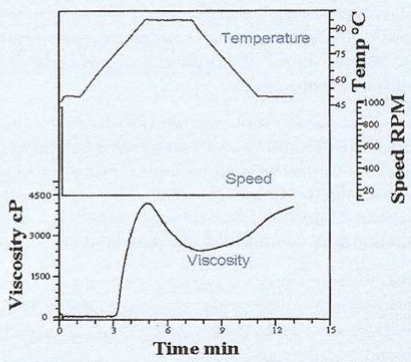


Fig. 1.1. Key components of the RVA.

Basic curve descriptors

Box 1.7. A Standard Profile

Stage	Standard (RVA STD1)
Initial temperature	50°C
Initial holding time	1 min
Heating time	3 min, 42 sec
Max. temperature	95°C
Hold at max. temperature	2 min, 30 sec
Cooling time	3 min, 48 sec
Final temperature	50°C
Final holding time	2 min
Total test time	13 min



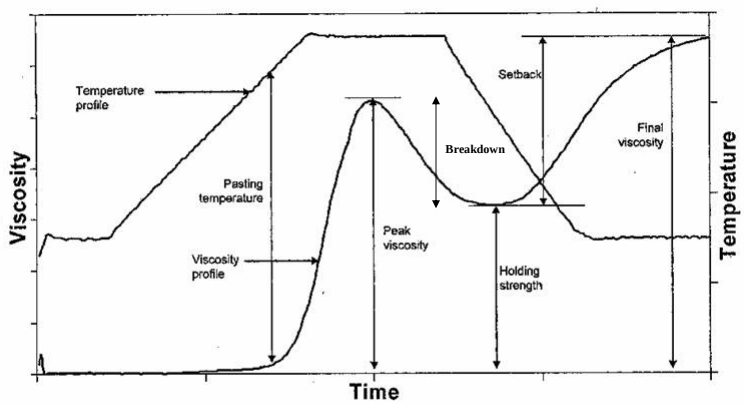
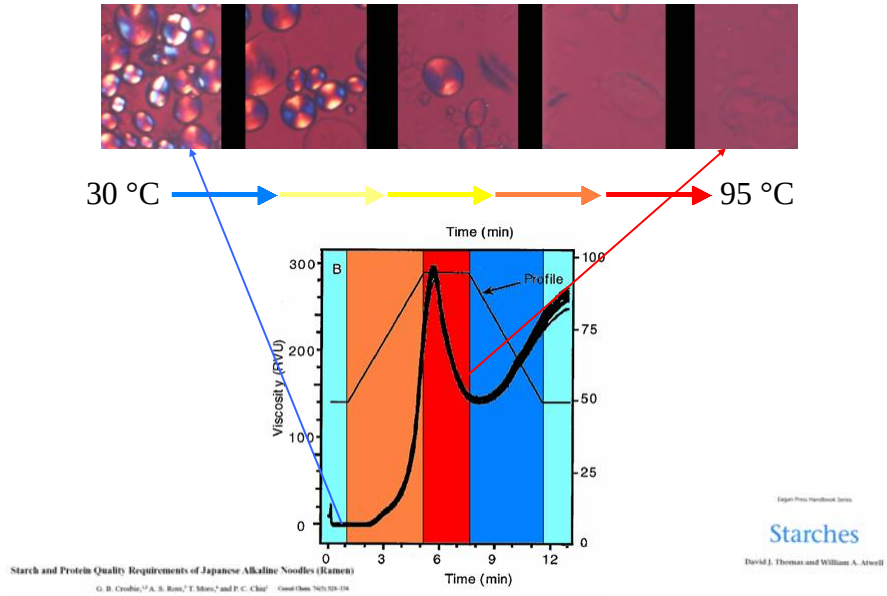


Fig. 2.1. Typical complete RVA curve, showing the main parameters used to describe the pasting. These terms are fully defined in Appendix 2.

Underlying principles



Photomicrographs
Ross A.S., (1995) Adding dextrans [1-6-alpha-D-glucans] to wheat flour: effects on flour components, dough rheology and end-product quality. Dissertation Abstracts International, B 56 (7) : 3524, 1996, thesis publ. 1995

Granule swelling and paste viscosity

- At temperatures < 100 °C without mechanical shear, swollen starch granules, enriched in amylopectin through amylose leaching, maintain their integrity
- The increase in **volume fraction** of starch granules in the suspension leads to an ***increase in viscosity*** of the paste

volume fraction, φ
Volume of a constituent of a mixture divided by the sum of volumes of all constituents prior to mixing.
See *fractions.*
G.B. 41; 1996, *68*, 998

IUPAC Compendium of Chemical Terminology 2nd Edition (1997)

MINI REVIEW
Aspects of the Physical Chemistry of Starch
R. Parker and S. G. Ring*
Institute of Food Research, Norwich Research Park, Colney Lane, Norwich, NR4 7UA, U.K.
Journal of Cereal Science 34 (2001) 1–17

- Einstein (Einstein A. 1906. Ann. Phys. 19, 289) derived an equation that gives an approximation for viscosity of particulate suspensions of spheres

$$\eta^* = \eta_o(1 + 2.5\phi)$$

- This works for dilute solutions/suspensions where φ is < 0.01 after which flow disturbances and then high er order particle – particle interactions make η increase faster than predicted by the above equation…

$$\eta^* = \eta_o(1 + 2.5\phi + c\phi^2 + \cdots)$$

J. Am. Ceram. Soc., 88 [4] 1046–1049 (2005)
DOI: 10.1111/j.1551-2916.2005.00204.x

Effective Viscosity of Suspensions of Spheres

Chun-Hway Hsueh[*,**,§] and Paul F. Becher[*,**]

Granule swelling and paste viscosity

- At temperatures > 60 °C viscosity of starch pastes is **dominated** by the volume fraction occupied by the starch granules
  - *@ >60 °C solubilised amylose is slow to, or does not, aggregate*
  - *solubilzed amylose also causes η_0 to increase further deviating from the Einstein equation*

$$\eta^* = \eta_o(1 + 2.5\phi)$$

- At concentrations > 6% w/w for cereal starches the swollen gelatinized granules fill the entire volume and the paste is viscoelastic
  - In turn, its properties are affected by the **deformability** of the swollen starch granules and their relative susceptibility to breakdown by shear
  - **granule deformability** becomes especially important in foods/gels made with minimum to no shear

MINI REVIEW

Aspects of the Physical Chemistry of Starch

R. Parker and S. G. Ring*
Institute of Food Research, Norwich Research Park, Colney Lane, Norwich, NR4 7UA, U.K.

Journal of Cereal Science 34 (2001) 1–17

Granule swelling: constraints and enhancements

- Extent of amylopectin swelling is dependent on the extent of **crosslinking*** and the affinity of the network for the solvent - The network will swell until the osmotic pressure generated by the network, as a result of its affinity for the solvent, is balanced by the restorative stiffness of the network resisting swelling.
- Neutral amylopectins in general have similar affinities for water so it may be the **effective crosslinking*** of entangled amylopectin which limits swelling
  - then shear needs to be factored-in.
- Anionic amylopectins [e.g.; potato – lightly phosphorylated] swell greatly at low ionic strengths as like-charges aren't masked [mutual repulsion and chain extension]
- ***** *simple entanglements for native starches, for covalently crosslinked modified starches, crosslinking is an additional restorative force restricting the extent of swelling*

MINI REVIEW

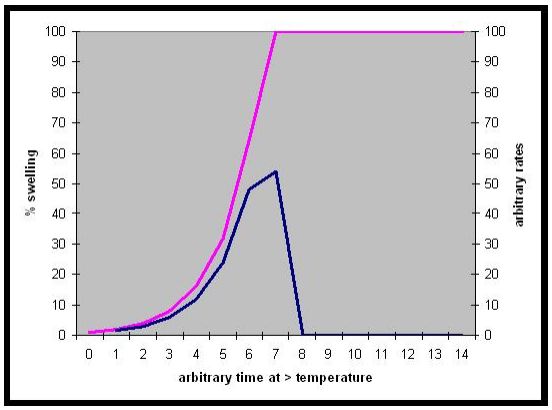
Aspects of the Physical Chemistry of Starch

R. Parker and S. G. Ring*

Institute of Food Research, Norwich Research Park, Colney Lane, Norwich, NR4 7UA, U.K.

Journal of Cereal Science 34 (2001) 1–17

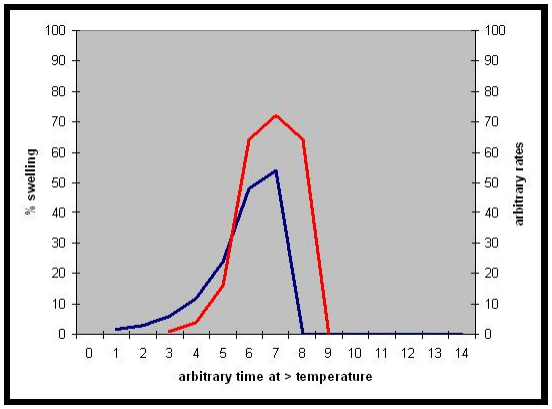
% granule swelling ∝ viscosity **rate of granule swelling**



No shear or other mechanisms of granule breakdown

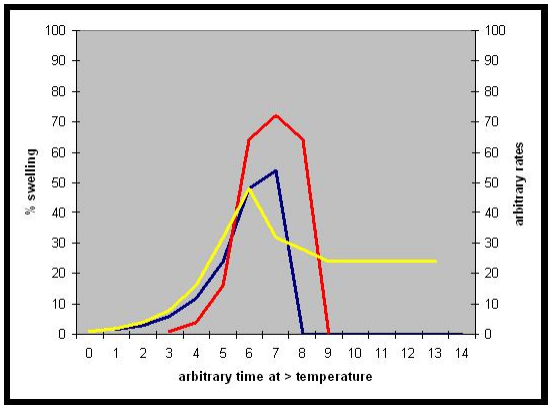
rate of granule breakdown

rate of granule swelling



rate of granule breakdown*

rate of granule swelling



% of potential for granule swelling ∝ viscosity

- Granule breakdown mechanisms
  - thermal
  - shear
  - amylase

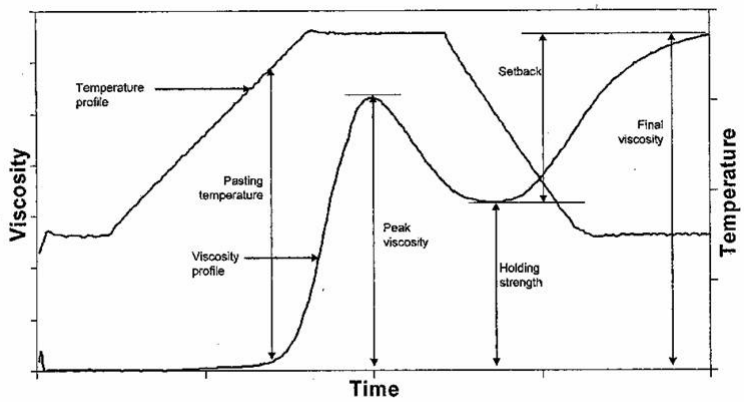


Fig. 2.1. Typical complete RVA curve, showing the main parameters used to describe the pasting. These terms are fully defined in Appendix 2.

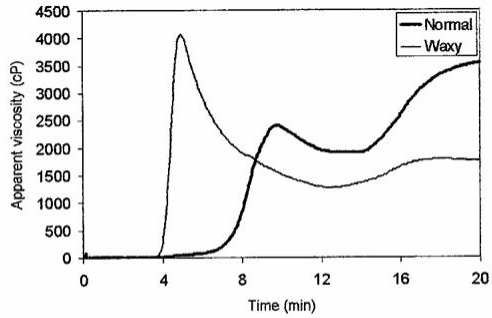
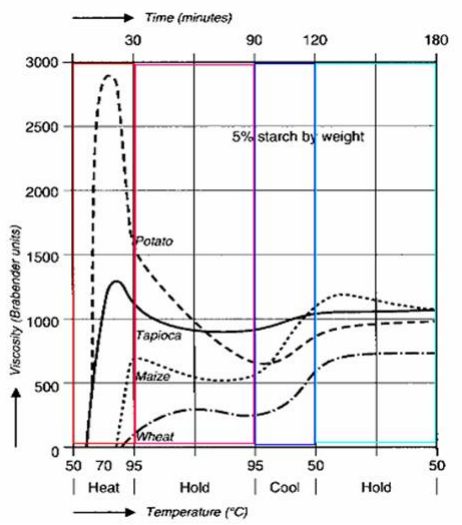


Fig. 2.2. RVA curves for waxy wheat starch and normal wheat starch, each with almost the same gelatinization temperature (as measured by differential scanning calorimetry).

Pasting differences: inter-varietal

note RATES of swelling and breakdown



Pasting differences: species

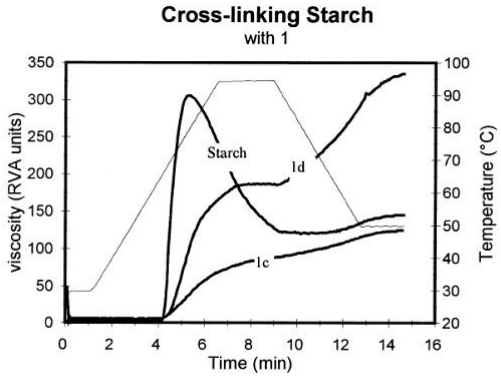


Fig. 1. RVA curves of starch and distarch 2-nitropropanediol (5% suspension; **1c**, $ds_{max} = 0.0019$; **1d**, $ds_{max} = 0.00098$).

ELSEVIER
Carbohydrate Research 310 (1998) 191–201
CARBOHYDRATE RESEARCH

Cross-linking of starch with bifunctional precursors of nitroalkenes

André Heeres[a], Henk A. van Doren[a,*], Kees F. Gotlieb[b], Ido P. Bleeker[c], R.M. Kellogg[d]

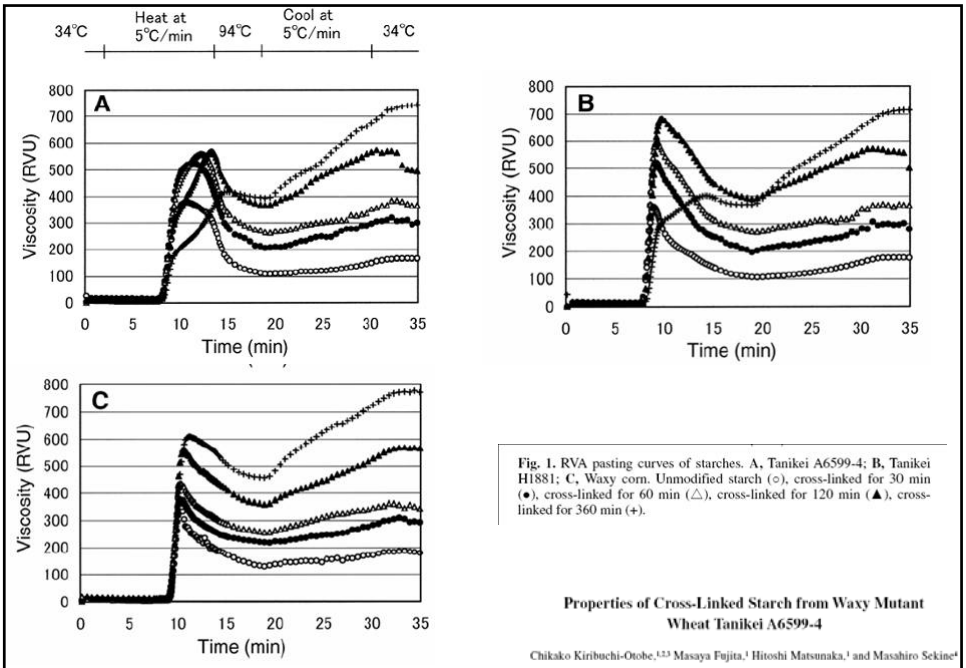


Fig. 1. RVA pasting curves of starches. **A,** Tanikei A6599-4; **B,** Tanikei H1881; **C,** Waxy corn. Unmodified starch (○), cross-linked for 30 min (●), cross-linked for 60 min (△), cross-linked for 120 min (▲), cross-linked for 360 min (+).

Properties of Cross-Linked Starch from Waxy Mutant Wheat Tanikei A6599-4

Chikako Kiribuchi-Otobe,[1,2,3] Masaya Fujita,[1] Hitoshi Matsunaka,[1] and Masahiro Sekine[4]

Cereal Chem. 83(6):590–594

Increasing η_0

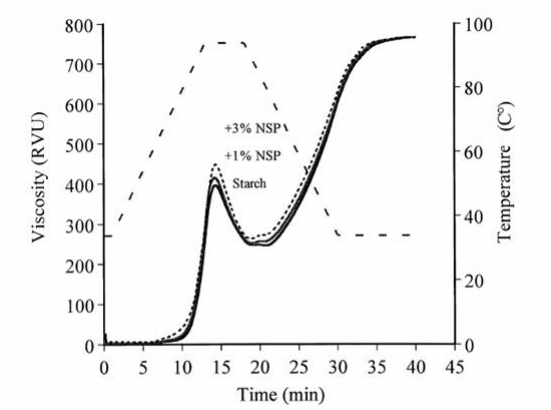


Fig. 1. RVA profiles for normal amylose starch (Norin 61) mixed with NSP rich fraction isolated from Kanto 107 flour (WIP/WSP = 1.201) – – – – Temperature profile.

ELSEVIER
Food Hydrocolloids 14 (2000) 295–303
FOOD HYDROCOLLOIDS
www.elsevier.com/locate/foodhyd

Influence of non-starch polysaccharides isolated from wheat flour on the gelatinization and gelation of wheat starches

T. Sasaki*, T. Yasui, J. Matsuki

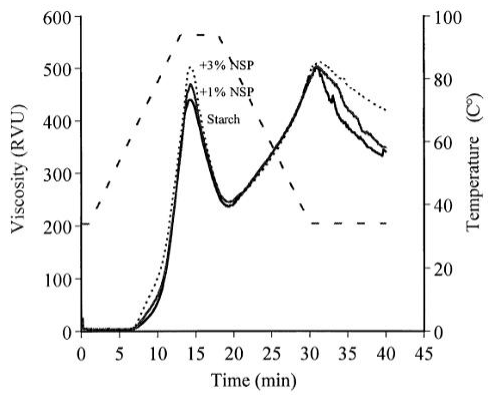


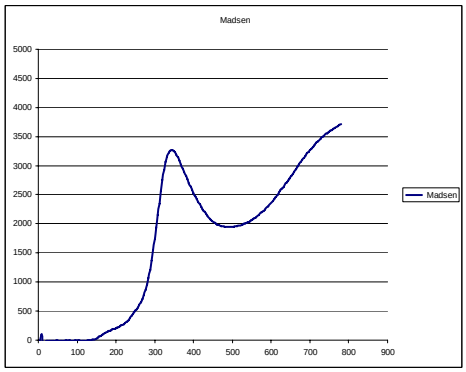
Fig. 2. RVA profiles for low amylose starch (Kanto 107) mixed with NSP rich fraction isolated from Kanto 107 flour (WIP/WSP = 1.201) – – – – Temperature profile.

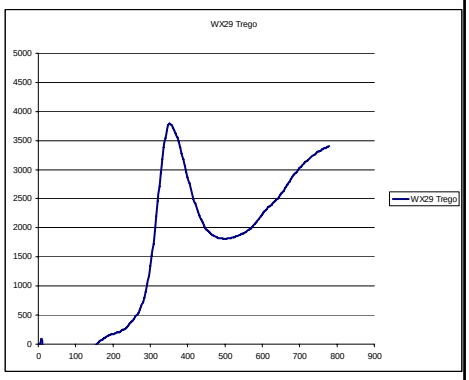
ELSEVIER
Food Hydrocolloids 14 (2000) 295–303
FOOD HYDROCOLLOIDS
www.elsevier.com/locate/foodhyd

Influence of non-starch polysaccharides isolated from wheat flour on the gelatinization and gelation of wheat starches

T. Sasaki*, T. Yasui, J. Matsuki

Amylose & amylopectin





normal

partial waxy

RVA std 1 temperature profile
apparent viscosity v time

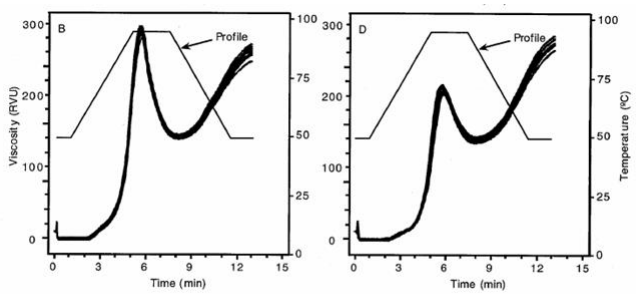


Fig. 2. Viscosity measured in Rapid-Visco Analyser units (RVU) for blends of sound and sprouted whole meal flour. Eradu tested in water (A) and 1 mM $AgNO_3$ (B). Kulin tested in water (C) and 1 mM $AgNO_3$ (D). Falling number values were 177–472 sec for Eradu and 161–427 sec for Kulin.

Vol. 76, No. 3, 1999 329

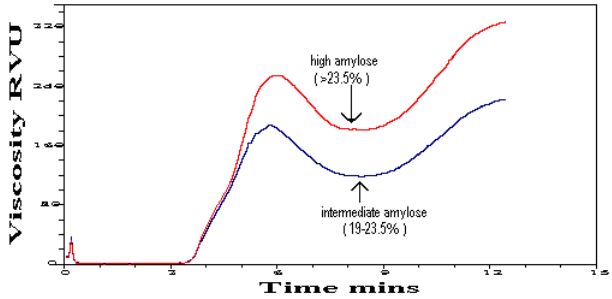
partial waxy normal

Starch and Protein Quality Requirements of Japanese Alkaline Noodles (Ramen)

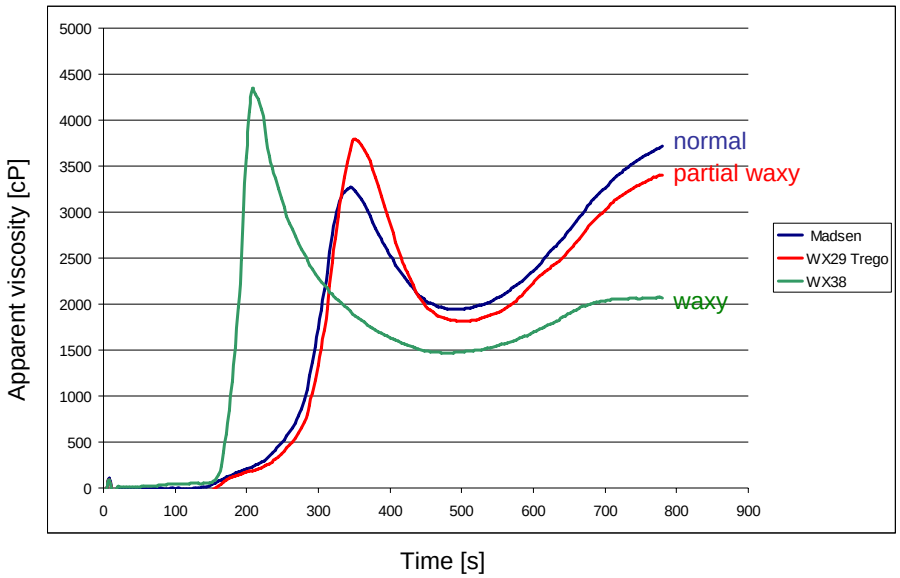
G. B. Crosbie,[1,2] A. S. Ross,[3] T. Moro,[4] and P. C. Chiu[1]

Cereal Chem. 76(3):328–334

Viscogram profiles (pasting cuves) of a high amylose rice type and an intermediate amylose rice type



USDA ARS Rice Research Unit, Beaumont TX



RVA std 1 temperature profile
apparent viscosity v time -- flour

Retrogradation / setback

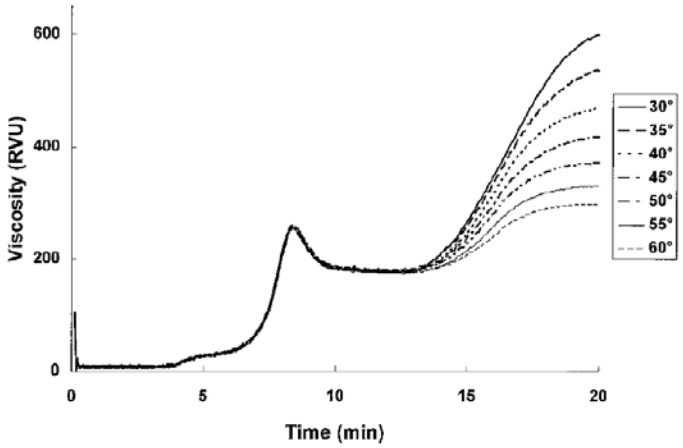


Fig. 4. Rapid Visco Analyser (RVA) viscograms of a wheat flour with final temperatures of 30, 40, 50, and 60°C. Initial temperature was 50°C.

Effects on Pasting Viscosity of Starch and Flour from Different Operating Conditions for the Rapid Visco Analyser[1]

Ian L. Batey[2,3] and Barbara M. Curtin[2]

Cereal Chem. 77(6):754–760

Amylase

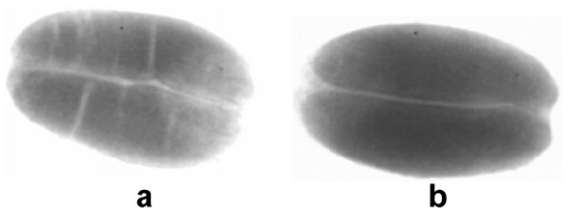


Fig. 1. X-ray images of (a) sprouted, (b) healthy wheat kernels (white speck indicates 'softened' endosperm in the sprouted kernel).

ELSEVIER

Available online at www.sciencedirect.com
ScienceDirect
Journal of Food Engineering 81 (2007) 509–513

JOURNAL OF FOOD ENGINEERING
www.elsevier.com/locate/jfoodeng

Detection of sprouted wheat kernels using soft X-ray image analysis

S. Neethirajan [a], D.S. Jayas [a,*], N.D.G. White [b]

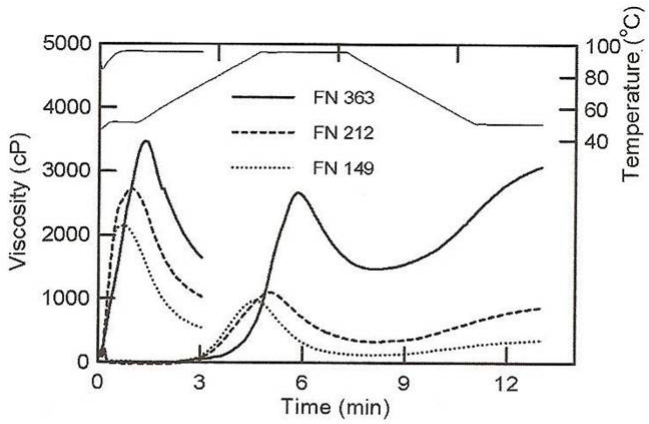


Fig. 3.1. Comparison of stirring number curves (left set) and STD1 pasting curves (right set) for three wheat-meal samples. The heating profile is shown at the top. FN is the falling number value, determined previously. (Courtesy C. Charrié)

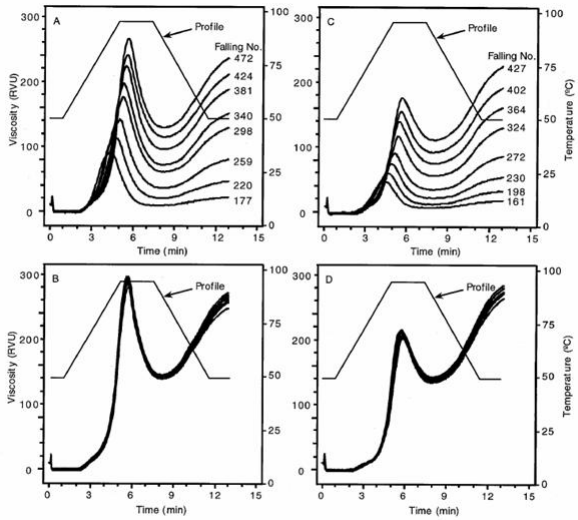


Fig. 2. Viscosity measured in Rapid-Visco Analyser units (RVU) for blends of sound and sprouted whole meal flour. Eradu tested in water (**A**) and 1 m*M* $AgNO_3$ (**B**). Kulin tested in water (**C**) and 1 m*M* $AgNO_3$ (**D**). Falling number values were 177–472 sec for Eradu and 161–427 sec for Kulin.

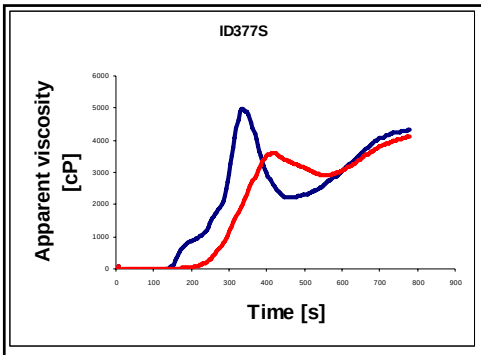
Vol. 76, No. 3, 1999 329

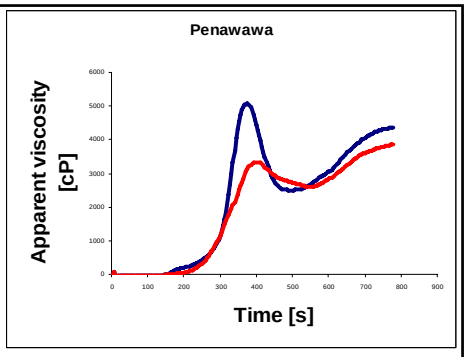
Starch and Protein Quality Requirements of Japanese Alkaline Noodles (Ramen)

G. B. Crosbie,[1,2] A. S. Ross,[3] T. Moro,[4] and P. C. Chiu[1]

Cereal Chem. 76(3):328–334

Flour versus starch

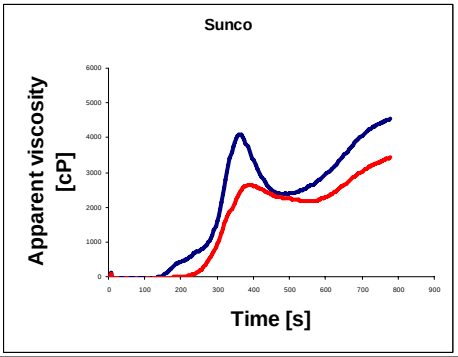


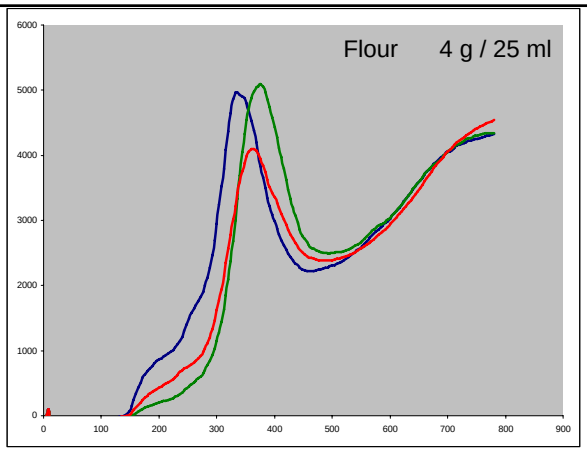


		peak	trough	final	% bd	final/peak
FLOUR	Sunco	4075	2378	4546	**58.4**	**111.6**
	Penawawa	5061	2495	4346	**49.3**	**85.9**
	ID377S	4972	2223	4323	**44.7**	**86.9**
STARCH	Sunco	2624	2167	3434	**82.6**	**130.9**
	Penawawa	3318	2599	3859	**78.3**	**116.3**
	ID377S	3605	2915	4115	**80.9**	**114.1**

Flour 4 g / 25 ml

Starch 3 g / 25 ml

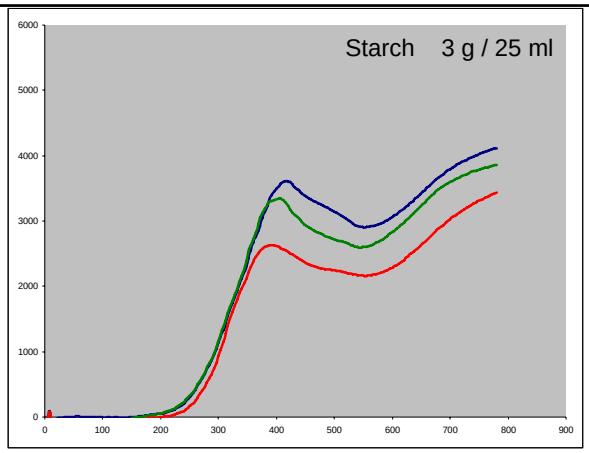




ID377S

Sunco

Penawawa

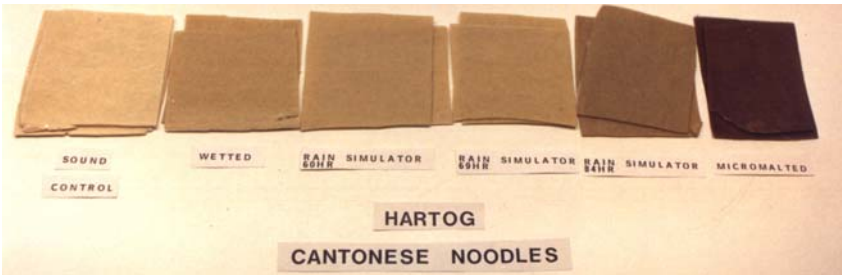


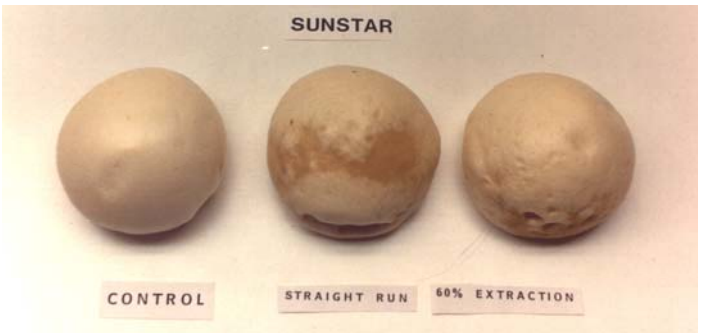
ID377S

Sunco

Penawawa

OTHER SPROUTING EFFECTS


SOUND
CONTROL
WETTED
RAIN SIMULATOR 60HR
RAIN SIMULATOR 60HR
RAIN SIMULATOR 84HR
MICROMALTED
HARTOG
CANTONESE NOODLES


SUNSTAR
CONTROL
STRAIGHT RUN
60% EXTRACTION