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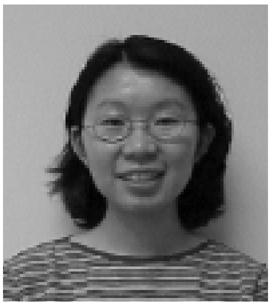
Average Shear Rates in the Rapid Visco™ Analyser Mixing System

Summary of a paper published in *Cereal Chemistry* 77(6), by K. P. Lai (pictured below)**, J. F. Steffe and P. K. W. Ng**



Objective

The Rapid Visco Analyser (RVA) is widely used to determine the viscous properties of starch slurries. The rotation of the pitched paddle keeps the starch particles suspended during heating and subsequent gelatinisation, but because the shear rates involved in the mixing process are unknown, the test results are highly empirical.

Evaluating shear rates in the RVA paddle-cup assembly is the first step towards evaluating the intensity of mixing, comparing results from other types of instruments, and exploring the potential of the RVA to measure basic rheological properties of other fluid foods.

The objective of this study was to find the average shear rates in the RVA system using mixer viscometry methods.

Materials and Methods

The average shear rates in the RVA were evaluated using the matching viscosity assumption proposed by Metzner and Otto (1957). The idea involves comparing the power curves of Newtonian and non-Newtonian fluids assuming a matching viscosity.

To determine the viscometer constant (k'), the torque output from the RVA was needed. To do this an adaptor was made to connect the paddle-cup to a conventional rotational viscometer (Haake RV12) for simultaneous torque measurement and precise speed control.

The mixer coefficient (k'') was calculated with data from several Newtonian fluids (Table 1) over a speed range of 100-300 rpm. Using the constant value of k'' and various non-Newtonian fluids (Table 2), k' was determined at different angular velocities.

TABLE 1. NEWTONIAN FLUIDS FOR ACQUIRING TORQUE CURVE DATA

Fluid	Newtonian Viscosity (Pa sec.)
Silicone Oil (Brookfield Engineering)	0.10
Silicone Oil (Brookfield Engineering)	0.49
Glycerine (Columbus Chem. Ind.)	0.83
Silicone Oil (Brookfield Engineering)	5.1
Polybutene (Cannon Instrument Co.)	14.0
Pure Clover Honey (Meijer Inc.)	13.7

TABLE 2. RHEOLOGICAL PROPERTIES OF NON-NEWTONIAN STANDARDS

Non-Newtonian Standard	K (Pa sec.^{n})	n
2.0% Hydroxypropopyl methylcellulose (Dow Chemical Co.)	7.1	0.58
2.5% Hydroxypropopyl methylcellulose (Dow Chemical Co.)	12.0	0.64
1.0% Guar Gum (Sigma Chemical)	11.0	0.26

K - consistency coeffiecient ; **n** - shear thinning indices

The utility of the mixer viscometer constant (k') was tested by examining typical food products at room temperature (23 ± 1.5°C): corn syrup, mustard, ketchup and a bread flour slurry (prepared according to RVA method STD1). Results using the RVA impeller/cup sensor and a conventional concentric cylinder system were compared (Table 3).

TABLE 3. COMPARISON OF CONSISTENCY COEFFICIENT (K) AND SHEAR THINNING INDICES (n) FOR TYPICAL FOOD PRODUCTS

Food	RVA Impeller / Cup		Concentric Cylinder*	
Product	K (Pa sec.^{n})	n	K (Pa sec.^{n})	n
Karo corn syrup: Best Foods Division	6.1	1.0	4.9	1.0
Mustard: Reckitt & Colman	41.2	0.21	26.8	0.23
Ketchup: H J Heinz Co.	49.2	0.17	44.8	0.11
Flour Slurry: The Pillsbury Company	108.6	0.22	66.8	0.34

*Haake VT550

Results

Torque curve results for the Newtonian fluids were plotted (Figure 1) and the mixer coefficient (k'') calculated as the reciprocal of the slope of the curve: k'' = 2000 rev./m³.

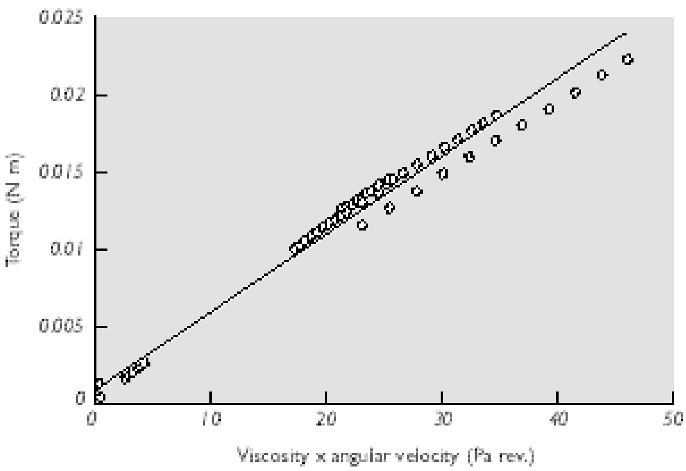


Figure 1. A plot between mixer torque and the product of viscosity and angular viscosity.

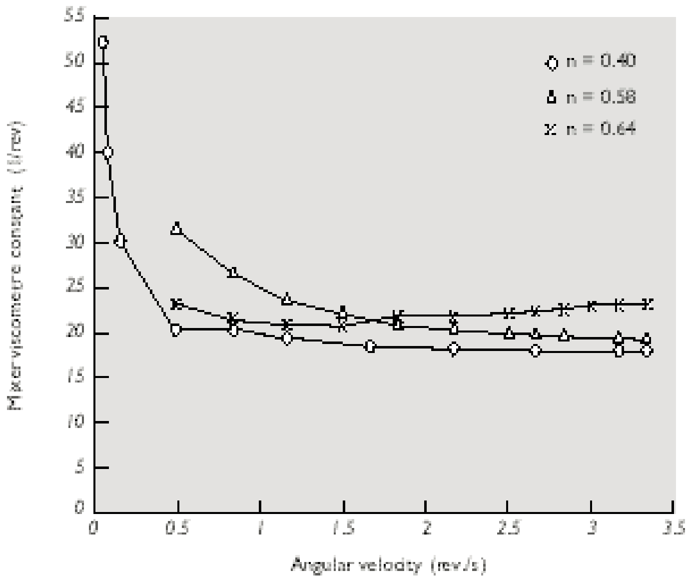


Figure 2. A plot between the mixer viscometer constant and the angular velocity of non-Newtonian fluids with varying values of the flow behaviour index (n).

The mixer viscometer constant (k') was influenced by both the angular velocity and the flow behaviour index (Figure 2). At speeds above 60 rpm, the value of k' is relatively constant, and equal to an average value of 20.1/rev.

Comparing rheograms for four food products produced using the RVA sensor system and a conventional concentric cylinder system shows curves with similar trends and magnitudes (Figure 3). Hence the average shear rate (in units of 1/s) in the RVA system may be calculated as 20.1 multiplied by the angular velocity given in revolutions per second.

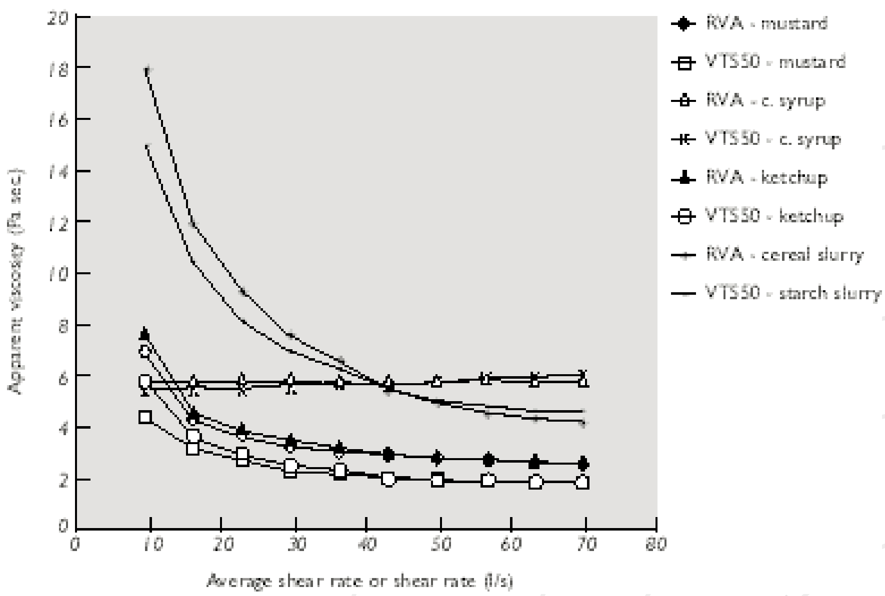


Figure 3. A plot of apparent viscosity and average shear rate (RVA data) or shear rate (VT550 data) for various food products.

Conclusions

Under the conditions of this study, a constant value of the mixer viscometer constant equal to 20.1/rev. provides a good estimate for calculating the average shear rate present in the RVA when mixing speeds range from 60 – 210 rpm (1.0 to 3.5 rev./sec.).

TIPS & TRICKS

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Correcting for Sample Moisture

A question which is frequently asked is: will it be sufficient to change only one weight parameter when correcting for moisture content in an RVA analysis? Adjusting only one weight means that the total volume in the canister differs depending on the moisture of the sample.

Here we show what happens to the viscosity profile and stirring number of a wholemeal wheat sample if the total volume in the canister is changed and the concentration of the sample is kept constant.

Standard 1 Viscosity Profile

A wholemeal sample with known moisture content was tested on an RVA-4 using the Standard 1 profile and 4.0 g wholemeal in 25.0 mL water. The profile was then compared to those using sample weights of 3.8 g and 4.2 g, representing moisture changes of approximately ± 5 %.

The Standard 1 profiles (Figure 1) show good repeatability between replicates. However, from the pasting curves, with the exception of the pasting temperature and the derived breakdown values, there were significant differences in all measured viscosity and time parameters between samples of different weights. Thus changing the total volume in the canister altered the pasting behaviour of wholemeal wheat.

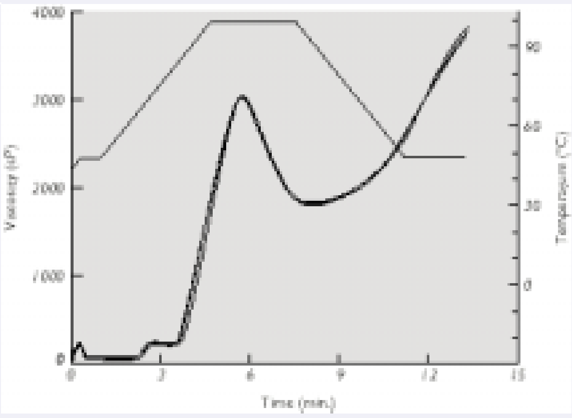

Figure 1. RVA pasting curves of wholemeal wheat at different total canister volumes.

Stirring Number

Stirring numbers for the three weights were determined using the stirring number profile.

Stirring number profiles are shown in Figure 2. It was expected that the larger sample weight resulted in a longer peak time, since it would take a longer time to heat up a larger volume. However, there were no significant differences in stirring number between samples of different weights. Thus stirring number of wholemeal wheat did not appear to be affected by total canister volume.

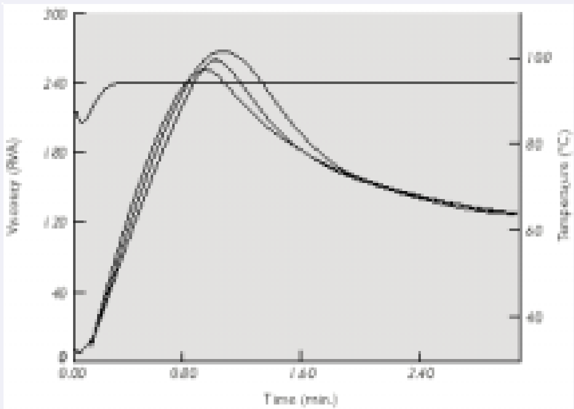

Figure 2. Stirring number curves of wholemeal wheat at different total canister volumes.

Recommendations

Peak and final viscosities of a sample are important parameters to consider in product development, as they give an idea of how the product may behave during and after processing. Since these parameters were significantly affected by changing the total volume in the canister during an RVA test, it is recommended that the volume in the canister be kept constant for all RVA tests. This means that in correcting for moisture content, both the sample and buffer weight should be adjusted to keep the total volume in the canister constant.

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RECENT REFERENCES MENTIONING THE RVA™

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