INDUSTRIAL RHEOLOGY FOR FOOD
SOME USEFUL APPLICATIONS FOR PROCESS OPTIMIZATION AND CONSUMER USABILITY

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ABSTRACT

People active in rheology need to part industrial rheology from academic rheology, separating the two paths simply by the TIME-scale. Industial rheology is forced to submit itself to quick and user-friendly methods in order to save time, not to be time-consuming.

INTRODUCTION

Industrial rheology could be devided into eighter continously; direct process-monitoring or discontinous measurements; product development and analyses in laboratory environment.

Existing instrumentation for continous measurement will only give information about equilibrium viscosity in a product, which is only a small part of the total rheological behavior.

The structure of the material is destroyed during continous monitoring, hence many revealing rheological parameters are not measurable. Discontinous, or laboratory rheology, gives far more information about the material behavior, and consequensly the main part of this lecture will be devoted to laboratory work.

Modern rheology for foods

Modern instruments has made rheology extremely useful in the food industry for optimizing production lines, predicting "in use"-behavior by the consumer and storage stability. Rheology has long been recognised as a useful index in relating the physical properties of viscous and viscoelastic modulus to food texture and consumer perception of the product. Following examples will give some idea of the versatility for industrial rheology in food research and quality control.

As most food processes are driven by a FORCE, a Controlled Stress Rheometer has been used to measure under real life-conditions. Most pumpings are driven by pressure (force) for foods. Fillings, squeezing out of a tube or spooning up are also conditions driven by a force. For accurate and precise measurements the rheometer used had an automatic/programmable gap closure. This is important for all structured materials such as foods, to ensure a repeatable treatment of the sample after loading, and smallest possible deformation before measurement.

Temperature dependant processability

Temperature is an important parameter in rheology, and most certanly for foods. Therefore all measurements where carried out on a rheometer with an electronic temperature control with a heating and cooling rate of 1° /sec from −20° to +99,9°C. Providing sufficient time is given for the sample to reach equilibrium temperature by each degree, such an equipment can be used to determine and measure the rheological behavior as a direct function of the temperature, as in real life.

Fig. 1 CHANGE IN BUTTER VISCOSITY WITH TEMPERATURE

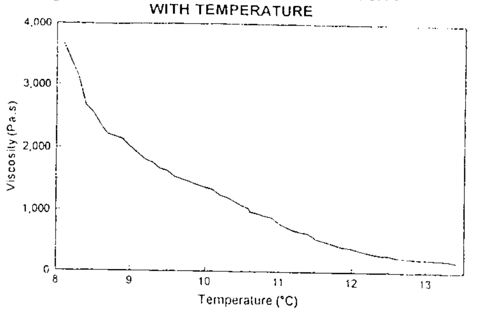

Figure 1. Temperature sweep of butter to simulate its viscosity in a refridgerator and warming up to room temperature, as in real life.

This measurement gives valuable information about its spreadability for different temperatures. How well it spreads will depend on the time the butter has been left to warm up, and thereforethe temperature it has reached. The same measurement will be useful for all spreads that undergo different temperatures.

Reduced fat content changes the rheological behavoir

To appeal to the health-conscious consumer, most food producers are reformulating products. In such a work it is important to ensure that the texture and taste of "redesigned" products are not changed. This is a difficult task as some foods depend on their fat-content for their richness. The following measurements compare different formulation of mayonnaises

Fig. 2 COMPARISON OF MAYONNAISES - FLOW

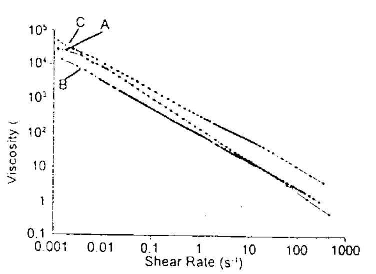

Figure 2. A simple flow curve to relate viscosity to shear rate.

A, B and C, containing 11g fat, 7g fat and 3g of fat per serving. Mayonnaise C was choosen in the end as the "reduced fat" product by this manufacturer. All products shear thinned well and the relative viscosity indicates that B should spread more easily than the other two. This might give a lack of richness, although its fat consistent is higher than C.

Fig. 3 COMPARISON OF MAYONNAISES - CREEP

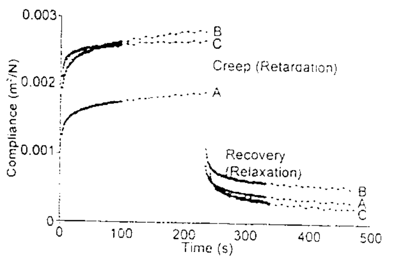

Figure 3. A creep curve to examine the way the products respond to a constant low stress.

A constant low stress can simulate eg gravity after spooning. Product A exhibit the greatest rigidity (moves less over time) and should appear richest. This behavoir is important as a rigid behavoir is desirable for maintaning desirable shape/decoration after squeezed out or spooned. B and C is simular. Creep is a useful method for predicting levelling and sagging behavoir of sauses etc.

Fig. 4 COMPARISON OF MAYONNAISE - OSCILLATION

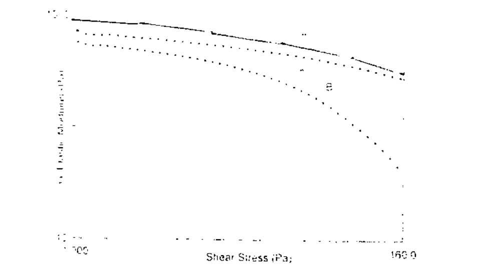

Figure 4. An oscillation test shows the viskoelastic property G´ (storage modulus) using a stress sweep.

Dynamic oscillation is the most sensitive way of resolving differences in the samples at rest ie the structure when spooning the product from a jar. Mayonnaise A has the highest elasticity indicating the strongest structure and should therefore appear thickest when dispensing.

Tailoring structure for different containers.

Ketchup is a good example of the "two-container-market", where glass bottlesand cheaper sqeeze dispensers are used for the same product, to meet different consumer demands. The sauses for these different containers, need to be simular in taste, colour and final structure on the plate, but they also need to be different in their dispensing proporties. When the ketchup is used in a glass bottle, it is not expected to flow freely until the bottle is shoked quite hard. In the plastic bottle on the other hand, the kethcup is expected to flow by a gentle squeeze (pressure) during some seconds.

In the following expermiment two different formulation of ketchup, A and B, from the same manufacturer are compared. Material A has been formulated for glass bottles while material B is used for plastic dispensers.

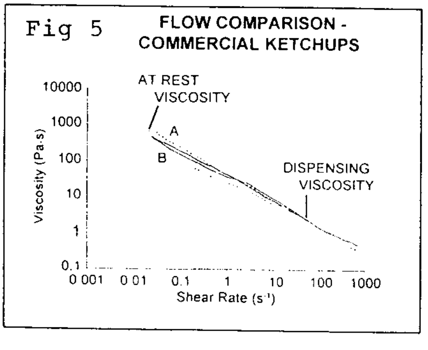

Figure 5. Viscosity against shear rate data under both increasing and decreasing stress.

As expected both A and B exhibit shear thinning behavior and A shows a higher rest viscosity (apparent thickness). Ideally, ketchup should exhibit rapid recovery from the shear thinning (structure braking) behavior for a tempting apparence on the plate. This behavior is exhibit by ketchup B.

Material A exhibit time dependant structure "Thixotropy", which will result in a slower, time dependant rebuilt of structure after break down.

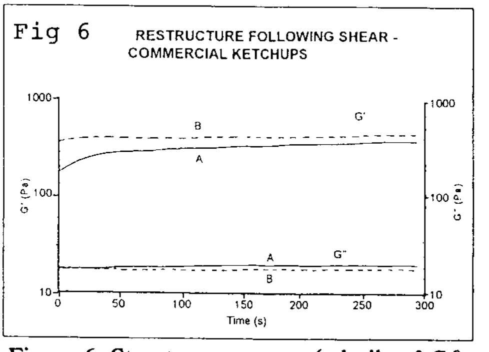

Figure 6. Structure recovery (rebuilt of G') over time with a constant stress and frequency.

The samples have been presheard simulating how it beeing squeezed/shooked out onto a plate. Ketchup B exhibit a higher level of structure (storage modulus), but ketchup A increases and builds up a structure simular to B over time. The conlusion is that allthoug A and B dispense differently, their final appearance on the plate is comparable.

Summary

Modern instrumentation enables quick and userfriendly production control and development in the laboratory to ensure that desired rheology is present in the product. Different test methods can be linked together to simulate a whole process, without changing the sample.

Examples used in this lecture have showed methods used in industrial rheology for process optimization and the prediction of consumer usability. Industial rheology of more academic character for research, depends of couse on the time scale permitted for each project.

ACKNOWLEDGEMENT

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