Evaluation of a helical ribbon impeller as a viscosity measuring device for fluid foods with particles

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Abstract:
The traditional methods of measuring viscosity with rotational viscometers, i.e. cone-plate and concentric cylinder systems, are often not suitable for suspensions. To be able to measure viscosity on suspensions mixer viscometers have been developed. In this study a new design of a helical ribbon impeller has been evaluated and the Metzner-Otto approach has been used to calibrate the impeller. Different kinds of food products were studied. The Metzner-Otto parameter obtained from tomato products was lower than those obtained from starch products. The study showed that the Metzner-Otto parameter varied but seemed rather to be dependent on the composition of the food material than on the flow behaviour index. The impeller could handle high concentration of quite large particles. This type of helical ribbon impeller viscometer is thus recommended for rheological studies of suspensions with high concentration of particles.

Zusammenfassung:
Die traditionellen Methoden, um Viskositäten in Rotationsviskosimetern zu messen, also zum Beispiel in Kegel-Platte- und konzentrische Zylindersysteme, sind häufig nicht für Suspensionen geeignet. Um deren Viskositäten zu messen, wurden Mischer-Viskosimeter entwickelt. In der vorliegenden Studie wird eine neue Kalibrationsmethode für den Helixrührer evaluiert, wobei das Metzner-Otto-Verfahren benutzt wird. Wir untersuchen eine Reihe unterschiedlicher Lebensmittelprodukte. Für Tomatenjuice erhalten wir einen geringeren Metzner-Otto-Parameter als für Stärke-Produkte. Die Studie zeigt, dass der Metzner-Otto-Parameter zwar variiert, aber mehr von der Zusammensetzung des Lebensmittelprodukts als vom Fließindex abhängt. Die Rührer kommen mit hohen Konzentrationen relativ großer Teilchen zurecht. Dieser Typ eines Helixrührer-Viskosimeters ist somit geeignet für rheologische Studien an Suspensionen mit hohen Partikelkonzentrationen.

Résumé:
Les méthodes traditionnelles qui mesurent la viscosité avec des viscosimètres rotatifs, tels que systèmes cône-plan et cylindres concentriques, sont souvent mal appropriés pour les suspensions. Afin de pouvoir mesurer la viscosité des suspensions, des viscosimètres mélangeurs ont été développés. Dans cette étude, une nouvelle conception d'agitateur en forme de ruban hélicoïdal a été évaluée et l'approche Metzner-Otto a été utilisée pour calibrer cet agitateur. Le paramètre Metzner-Otto obtenu pour des produits à base de tomates est inférieur à ceux obtenus pour des produits amidonnés. L'étude a montré que le paramètre Metzner-Otto varie mais semble plutôt dépendre de la composition du matériau alimentaire que du comportement de l'indice d'écoulement. L'agitateur a pu fonctionner à des grandes concentrations en particules assez grosses. Ce type d'agitateur à ruban hélicoïdal est donc recommandé pour des études rhéologiques de suspensions possédant de grandes concentrations en particules.

Key Words: food rheology, suspensions, mixer rheometer, helix ribbon impeller, Metzner-Otto

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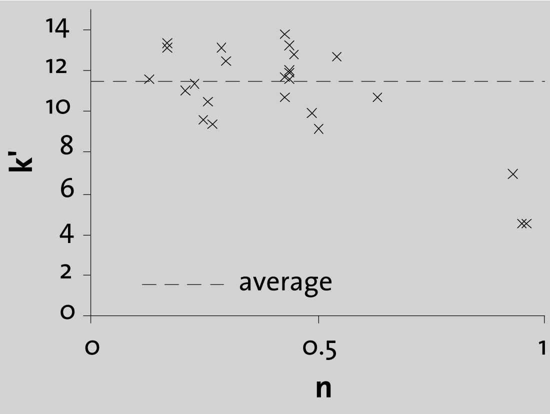

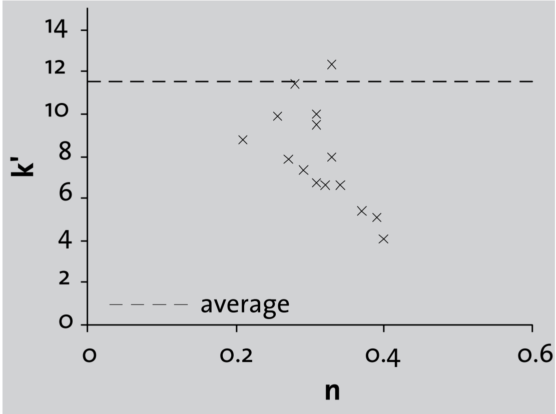

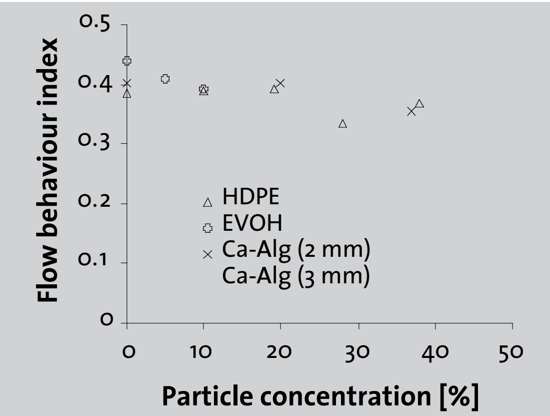

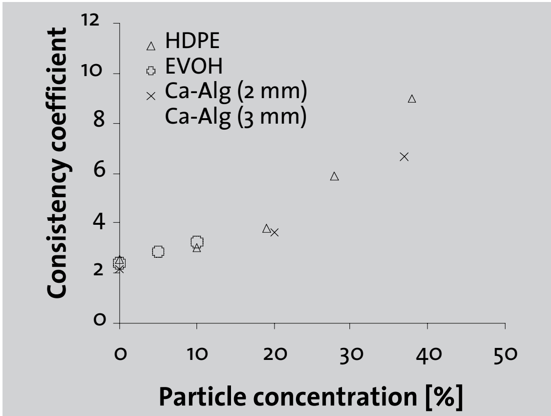

Figure 6 (left above): Experimental k' values for starch products.

Figure 7 (right above): Experimental k' values for tomato, fruit and vegetables products.

Figure 8 (left below): The effect of particle concentration on the flow behaviour index.

Figure 9 (right below): The effect of particle concentration on the consistency coefficient.

slightly different. The products in which starch is a component have values of *k'* around 11.5 (Fig. 6). For these products a higher value of n seems to generate lower value of *k'*. However, only three of the analysed products show flow behaviour index higher than 0.65, which are too few to draw any general conclusions.

For all but one of the tomato products and the products based on fruit and vegetables *k'* values lower than the average were obtained (Fig. 7). The highest values of *k'* in the tomato group was obtained from the tomato products which contained added starch. It is however unknown if any of the other tomato products contained added starch, as it was not included in the declaration of contents. Also for tomato, fruit and vegetables products a higher value of *n* seemed to generate a lower value of *k'*.

The results in this study contradict the results obtained by others as no clear dependence on *k'* by the flow behaviour index could be found. From the experimental results in this study the Metzner-Otto parameter seems neither to be dependent upon the flow behaviour index nor does it seem to be constant. If anything, the fluid's structure and composition seem to affect the parameter. The study of the possible particle concentration in the fluid showed that the helical ribbon impeller could handle concentrations up to about 40 wt%. As the fluids could not be measured with a standard geometry the average *k'* of 11,5 was used for calculations of shear rate and viscosity. The results showed that the values of the power law parameters *K* and *n* at low particle concentrations were not much different from the values obtained for the solution without particles. At higher concentrations, above 20 wt%, the difference became greater (Figs. 8 and 9).

CONCLUSIONS

Despite the uncertainty in the *k'* the helical ribbon impeller can be used for rheological studies of particle suspensions. For fluids with particles, which have to be removed prior to measurement with standard geometries, the viscosity obtained with the helical ribbon impeller might predict the power law parameters *K* and *n* more accurate than the viscosity obtained from the fluids from which the particles have been removed.

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NOMENCLATURE

d	Impeller diameter [m]
K	Consistency coefficient [Pas^n] (Power law fluid)
K_p	Constant defined by Eq. 2
M	Torque [Nm]
N	Impeller rotational speed [s^{-1}]
n	Flow behaviour index (Power law fluid)
N_p	Power number (Eq. 3)
Re	Reynolds number (Eq. 4)
k'	Metzner-Otto parameter (defined by Eq. 1)
$\dot{\gamma}$	Shear rate [s^{-1}]
μ	Viscosity [Pas]
ρ	Density [kg/m^3]

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