Bostwick Degree and Rheological Properties: an Up-to-date Viewpoint

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Abstract:
The correlation between the Bostwick degree and the static rheological properties of yield stress food fuids is first revisited and then reformulated in this work. The role of the yield stress in the free surface flow of the Bostwick test is studied using dimensional analysis. Results from experiments on 48 different samples of yield stress fluids are considered and included to check the adequacy of the proposed correlation. Asymptotic dynamic behaviour is also presented and discussed as a mechanism of complete self similarity with respect of the dimensionless time. This approach would seem to support the opinions in favor of the yield stress as a key parameter, and thus offers an interesting new viewpoint useful to both future experiments on the Bostwick test and studies of 'dam-break' like dynamics.

Zusammenfassung:
In dieser Arbeit wird die Wechselbeziehung zwischen dem Bostwick-Grad und den statischen rheologischen Eigenschaften von flüssigen Nahrungsmitteln behandelt und neu formuliert. Die Rolle der Fliessspannung im freien Oberflächenfluss des Bostwick-Tests wurde mit Hilfe der Dimensionsanalyse untersucht. Resultate von Experimenten mit 48 verschiedenen Proben von Flüssigkeiten mit einer Fliessspannung wurden in diese Studie einbezogen, um die Richtigkeit der vorgeschlagenen Wechselbeziehung zu überprüfen. Zusätzlich wird eine Analyse des asymptotischen dynamischen Verhaltens vorgestellt und diskutiert. Dieser Ansatz scheint die Theorie der Fliessspannung als Hauptparameter zu unterstützen, und bietet folglich eine neue und interessante Sichtweise, welche sowohl für zukünftige Experimente mit dem Bostwick-Test als auch für Untersuchungen von "dammbrechungsähnlicher" Dynamik nützlich ist.

Résumé:
Dans ce travail la corrélation entre le degré Bostwick et les propriétés rhéologiques statiques des fluides alimentaires avec contrainte seuil est d'abord revisitée et ensuite reformulée. Le rôle de la contrainte seuil dans l'écoulement de Bostwick est étudié en utilisant l'analyse dimensionnelle. Les résultats des expériences entreprises sur 48 échantillons différents de fluides avec contrainte seuil sont aussi considérés et inclus pour vérifier l'adéquation de la corrélation proposée. Une analyse du comportement dynamique asymptotique est également présentée et discutée. Cette approche semblerait soutenir les avis en faveur de la contrainte seuil comme paramètre principal, et offre ainsi un nouveau point de vue, intéressant et utile aux futures expériences sur l'essai de Bostwick de même que sur les études sur la dynamique de rupture.

Key words: Bostwick consistometer, yield stress, viscoplastic fluids, food rheology, dimensional analysis, fruit purees

1 INTRODUCTION

Many products from the food industry show a non-Newtonian rheological behavior of the shear thinning type with the presence of yield stress [1 - 3]. From an engineering viewpoint, the yield value can be considered a characteristic of several food fluids, typically of those whose raw products have a high content of fibers (e.g. fruits and vegetables). The static rheological characteristics of these products have been extensively described by means of two or three parameter models, such as the Ostwald-deWaele or the Herschel-Bulkley [1, 4, 5]. Among the rheological properties time dependency is considered to be relevant for particular applications, i.e. in cases that imply either relevant material degradation or structure formation [5, 6]. On the contrary, the variability of viscosity on shear, i.e. namely the apparent viscosity, is always a key issue. Its importance ranges from speculative to more

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This would avoid to propagate and turn into confusion the 'ignorance' that the Bostwick measure implicitly introduces in the results. Future steps should therefore aim at introducing the nonlinear role of yield stress in the front evolution following the traces already suggested by [18, 19, 20, 23]. Although the numerical work by Mei and Yuhi [19] already considered the limiting case of rectangular channel, some additional efforts could still help to complete the studies already done by [14, 15]. In particular, this could be done by extending the results in [19] to a horizontal bed and by comparing both numerical and experimental results.

In conclusion, although this work did not lead to a physical model, it allowed to critically analyze the role of the involved quantities, and to obtain novel results of broad scientific interest. Only yield stress fluids were deliberately focused on here, which are relevant to several fields of engineering. Indeed, beyond food engineering - in which this correlation can be useful to control the food process quality in modern industrial plants - many other processes of geophysics [23] and hydraulics [24, 25] can potentially use such an analysis. As an example, the Bostwick test offers the possibility to study the dynamics succeeding a rapid initial transitory. This process shows many similarities with the problems of 'dam-break' of very viscous fluids (see, for example [25]), but at a smaller scale.

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