DEPENDENCIES OF LIGHT BREW RHEOLOGIC PROPERTIES ON VARIOUS PARAMETERS

ZAVISNOST REOLOŠKIH OSOBIINA BELOG HLEBA OD RAZLIČITIH PARAMETARA

Peter HLAVÁČ, MSc
Department of Physics, Slovak University of Agriculture in Nitra, Tr. A. Hlinku 2, SK - 949 76 Nitra, Slovak Republic,
e-mail: Peter.Hlavac.MF@uniag.sk

SUMMARY

During the quality valuation of food materials it is important to know their physical properties, particularly mechanical, rheologic, electric and thermophysical properties. Physical quantities of materials are required in automatically controlled processes during manufacturing, handling and holding. The results of the measuring of rheologic properties of light brew are shown in this paper. The measuring was performed by digital viscosimeter Anton Paar (DV-3P). The sample of light brew was stored in a special cool box at the temperature of 3 °C and was measured on different days. The measurements were done after the temperature stabilization from 7 °C to laboratory temperature. Dependencies of dynamic, kinematic viscosity and fluidity on temperature and on the time of storing are described. The dependency of dynamic viscosity on temperature can be described by Arrhenius equation. Temperature dependencies of dynamic and kinematic viscosity of light brew are decreasing exponentially and in this temperature range almost linearly for all measurements. Dynamic and kinematic viscosity of sample had increased a bit with time of storing. Temperature dependencies of light brew fluidity are increasing exponentially and in this temperature range almost linearly for all measurements. Fluidity of sample had decreased a bit with time of storing. All drawn dependencies had very high coefficients of determination.

Key words: dark beer, dynamic and kinematic viscosity, fluidity, temperature, time of storing

INTRODUCTION

Measuring of light brew rheologic properties was performed by digital viscosimeter Anton Paar (DV-3P). Dynamic viscosity \( \eta \), kinematic viscosity \( \nu \), fluidity \( \phi \) and tangential tension \( \tau \) are included into rheologic properties. Materials, where internal friction is generated, can be characterized by viscosity. Dynamic viscosity is defined as a constant between tangential tension and gradient of layer velocity (grad \( \nu \)).

\[
\tau = \eta \text{ grad } \nu
\]

Physical unit of tangential tension is Pa and unit of dynamic viscosity is Pa.s, but for these types of liquids more often used unit is mPa.s. Kinematic viscosity is defined as a ratio between dynamic viscosity and density of used material.

\[
\nu = \frac{\eta}{\rho}
\]

Physical unit of kinematic viscosity is m\(^2\).s\(^{-1}\). Reciprocal value of dynamic viscosity is called fluidity and physical unit of fluidity is Pa\(^{-1}\).s\(^{-1}\).

\[
\phi = \frac{1}{\eta}
\]

Rheologic properties were measured by many authors. Buchar et al. (2005, 2003), investigated these properties of eggs yolk, milk products and ketchups. Severa et al. (2007) examined influences of storing on viscosity of egg fluids. Marudova and Zsivánovits (2005) described rheologic properties of pectin films. Hlaváč (2007) measured rheologic properties of plum jam. Biczó et al. (2005) examined methods for determination of rheologic properties of chocolate mass. Kubík (2006) examined influence of long term storage on apple flesh. During the quality valuation of food material it is important to know their physical properties particularly mechanical, rheologic and thermophysical (Božiková, 2005). Automatically controlled processes in manufacturing, handling and holding require the exact knowledge of physical quantities of materials. New methods are still developed, which make use of new modern apparatuses and microscopic components. Very fast development is possible to observe during the utilization of microwave in measuring properties of soil and food (Hlaváčová, 2002). Tóth and Opáth (2006) were concerned with physical and chemical properties of beer and they also described ways and equipments for beer filtration.

MATERIAL AND METHODS

The used sample of light brew was obtained from the Department of Animal Husbandry and Food Production of the Slovak University of Agriculture in Nitra.

The measuring was performed by digital viscosimeter Anton Paar (DV-3P). The principle of measuring by this viscosimeter is based on dependency of sample resistance against the probe rotation. The probe with signification R2 was used in our measurements. We were able to choose the frequency of probe rotation from 0.3 min\(^{-1}\) to 200 min\(^{-1}\). The duration of probe rotation was three minutes. The illustration in Fig. 1 show the dependency of dynamic viscosity on time of probe rotation (frequency of rotation was 200 min\(^{-1}\) and temperature 25 °C). Measurement process and final value of dynamic viscosity was not affected by few small bubbles.

The sample of light brew was stored in a special cool box at the temperature of 3 °C and was measured on different days during three weeks. Measurements were done after the temperature stabilization from 7 °C to laboratory temperature. Dependencies of light brew dynamic viscosity, kinematic viscosity and fluidity on temperature are drawn and same dependencies of light brew on time of storing are described.

Dependency of dynamic viscosity on temperature can be described by Arrhenius equation

\[
\eta = \eta_0 \ e^{\frac{E_d}{RT}}
\]

where : \( \eta_0 \) is reference value of dynamic viscosity, \( E_d \) is activation energy, \( R \) is gas constant and \( T \) is temperature.

This equation has decreasing exponential shape.
Fig. 1. Dependency of dynamic viscosity on the time of probe rotation with frequency of rotation 200 min⁻¹ (temperature 25 °C)

Sl. 1. Zavisnost dinamičke viskoznosti u toku vremena od rotacije sonde sa frekvencijom rotacije 200 min⁻¹ (temperature 25°C)

RESULTS

Dependencies of light brew dynamic viscosity on temperature after different time of storing are in Fig. 2. Progress of graphic dependencies can be described by a decreasing exponential function (4). These exponential functions are almost like linear functions in this temperature range for all dependencies. Small differences could be found only in coefficients of determination and higher values are in case of exponential function (Tab.1).

\[
\eta = A e^{-\left( \frac{t}{t_B} \right)}
\]  

(4)

Fig. 2. Dependencies of light brew dynamic viscosity on temperature after different time of storing: first measurement (+), second measurement after three week of storing (Δ).

Sl. 2. Zavisnost dinamičke viskoznosti belog hleba od temperature nakon različitog vremena skladištenja: prvo merenje (+), drugo merenje nakon tri nedelje skladištenja (Δ).

Temperature dependencies of light brew dynamic viscosity had a decreasing exponential shape (almost linear shape) for all measurements (Fig. 2) and it is also evident that dynamic viscosity had increased a bit with time of storing (Fig. 2).

Kinematic viscosity and fluidity were calculated from equations (1), (2). Dependencies of light brew kinematic viscosity and fluidity on temperature after different time of storing are on Fig. 3 and on Fig. 4. Progress of graphic dependencies can be described by decreasing exponential function (5) for kinematic viscosity and by increasing exponential function (6) for fluidity.

\[
v = C e^{-\left( \frac{t}{t_D} \right)}
\]  

(5)

Fig. 3. Dependencies of light brew kinematic viscosity on temperature after different time of storing: first measurement (+), second measurement after three weeks of storing (Δ).

Sl. 3. Zavisnost kinematske viskoznosti belog hleba od temperature nakon različitog vremena skladištenja: prvo merenje (+), drugo merenje nakon tri nedelje skladištenja (Δ).

Fig. 4. Dependencies of light brew fluidity on temperature after different time of storing: first measurement (+), second measurement after three week of storing (Δ).

Sl. 4. Zavisnost "fliudnosti" (recipročna vrednost dinamičke viskoznosti) belog hleba od temperature nakon različitog vremena skladištenja: prvo merenje (+), drugo merenje nakon tri nedelje skladištenja (Δ).
R2 (linear function) 0.996 786 0.996 446
R2 (linear function) 0.990 794 0.987 662
R2 (linear function) 0.990 868 0.987 686

It is evident that fluidity had decreased a bit with time of storing (Fig. 3). Temperature dependencies of light brew fluidity had an increasing exponential shape (almost linear shape) in this temperature range for all measurements. Coefficients of determination are a bit higher in case of the increasing linear function than in the increasing exponential function. Temperature dependencies of light brew fluidity had an increasing exponential shape (almost linear shape) in this temperature range for all measurements. Coefficients of determination are a bit higher in case of the increasing linear function than in the increasing exponential function. Measured values of dynamic viscosity and calculated values of kinematic viscosity and fluidity were obtained with good precision and all drawn dependencies had very high coefficients of determination.

ACKNOWLEDGEMENT: This work was supported by research projects VEGA 1/4400/07, VEGA 1/0643/09 of Slovak Grant Agency for Science, and by research project GA SPU I-08-000-11 of Grant Agency of Slovak University of Agriculture in Nitra.

LITERATURE