Chosen temperature dependencies of whisky rheologic and thermal properties

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Abstract. Information about physical properties of whisky is almost impossible to find. That is why this paper is concerned with some physical properties of chosen types of whisky. Our research was focused on rheologic and thermal parameters. Temperature can be included between the most significant parameters that influence physical properties of food. And that is the reason why this article deals with chosen temperature dependencies of whisky rheologic and thermal properties. Temperature dependencies of whisky dynamic and kinematic viscosity can be described by decreasing exponential function and temperature dependency of whisky fluidity has increasing exponential character. Dependencies of thermal conductivity, diffusivity and volume specific heat on temperature are characterized by increasing linear function.

INTRODUCTION

Whisky is an alcohol drink. Origins of the whisky are in Scotland and Ireland (Jackson, 2002), but nowadays its production is spread on several continents. Whisky is usually produced from these three basic ingredients: grains, water and yeasts. Different types of grains could be used, for example wheat, barley, corn and rye (Hoffmann, 2009). Malt is made out of grains and yeast assists in transformation of sugars to alcohol.

Particular sort of whisky depends mostly on the ingredients used during the production, on the used production method, and way and time of maturing in special containers (most frequently wood barrels). There are several types of whisky as single malt whisky, grain whisky, mixed malt whisky, blended whisky, etc. (Gasnier, 2005). Colour, odour and taste could be included between basic properties of whisky (Soole, 2010).

Physical properties of whiskies are not known and research of these properties is very important. Because of liquid character of whisky, are very significant rheologic properties, which can determine the quality of whisky. During the manipulation with whisky we can observe temperature changes, so the second type of very important physical properties is thermal.

MATERIALS AND METHODS

Our research was oriented on measuring of thermophysical and rheologic characteristics of whisky. There were measured two types of whisky – Grant's and Jim Beam from two different producers. During the experiments were measured thermal characteristics as: thermal conductivity, thermal diffusivity and volume specific heat. The second part of experiments was focused on measuring of rheologic parameters as: dynamic viscosity, kinematic viscosity and fluidity. Measuring of dynamic viscosity was performed by digital rotational viscometer Anton Paar DV–3P, and the principle of measurement is based on sample resistance against the probe rotation. Other rheologic parameters were calculated according to equations mentioned in Božiková – Hlaváč (2010). Measuring of thermal parameters was performed by instrument Isomet 2104. Measurement by Isomet is based on analysis of the temperature response of the measured sample to heat flow impulses (Božiková – Hlaváč, 2010).

Selected rheologic and thermal parameters were measured during the temperature stabilisation in temperature range (-5 – 27) °C. The temperature effect on viscosity can be described by an Arrhenius type equation:

$$\eta = \eta_0 \, e^{-\frac{E_A}{RT}} \qquad (1)$$

where η_0 is reference value of dynamic viscosity, E_A is activation energy, R is gas constant and T is absolute temperature (Figura and Teixeira, 2007).

Temperature dependencies of dynamic and kinematic viscosity can be described by decreasing exponential functions (2, 3) and temperature dependency of fluidity by increasing exponential function (4). Temperature dependencies of thermal conductivity, diffusivity and volume specific heat can be described by increasing linear functions (5, 6 and 7).

$$\eta = A \, e^{-B\left(\frac{t}{t_o}\right)} \qquad (2)$$

$$\nu = C \, e^{-D\left(\frac{t}{t_o}\right)} \qquad (3)$$

$$\varphi = E \, e^{F\left(\frac{t}{t_o}\right)} \qquad (4)$$

$$\lambda = G + H\left(\frac{t}{t_0}\right) \qquad (5)$$

$$a = I + J\left(\frac{t}{t_0}\right) \qquad (6)$$

$$c\rho = K + L\left(\frac{t}{t_0}\right) \qquad (7)$$

where t is temperature, t_0 is 1 °C, A, B, C, D, E, F, G, H, I, J, K, L are constants dependent on kind of material, and on ways of processing and storing.

RESULTS AND DISCUSSION

Results are presented as graphic relations of rheologic and thermal properties on temperature. Temperature dependencies of dynamic and kinematic viscosity are shown on Fig. 1 and Fig. 2 and temperature dependencies of fluidity are on Fig. 3.

It can be seen from Fig. 1 that dynamic viscosity of both whisky samples is decreasing with temperature. The progress can be described by decreasing exponential function, which is in accordance with Arrhenius equation (1). From Fig. 1 can be also seen that dynamic viscosity of both whisky samples were approximately same and that can be caused by same amount of alcohol content. Kinematic viscosity of whisky samples is decreasing exponentially with temperature (Fig. 2). Dependency of whisky fluidity on temperature is on Fig. 3. It is evident that fluidity of both whisky samples is increasing exponentially with temperature. All regression coefficients and coefficients of determination are shown in Tab.1. In all cases were the coefficients of determination very high.

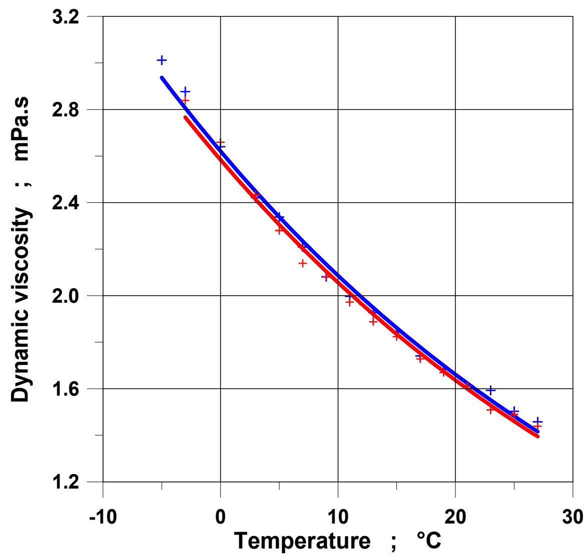

Figure 1
Temperature dependencies of whisky dynamic viscosity (Grant´s +, Jim Beam ○)

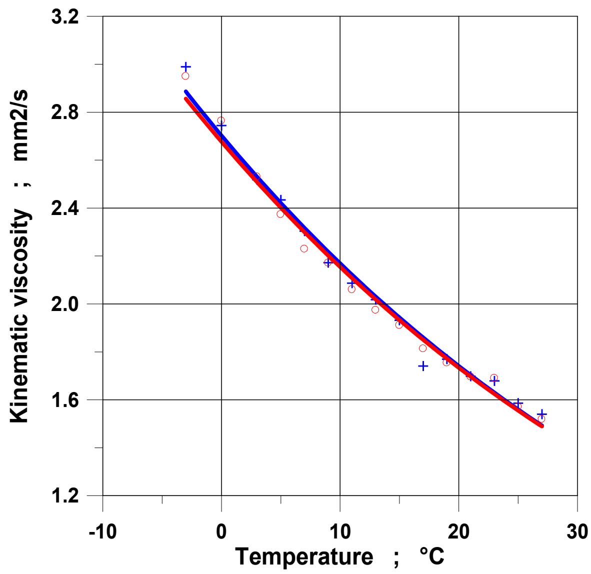

Figure 2
Temperature dependencies of whisky kinematic viscosity (Grant´s +, Jim Beam ○)

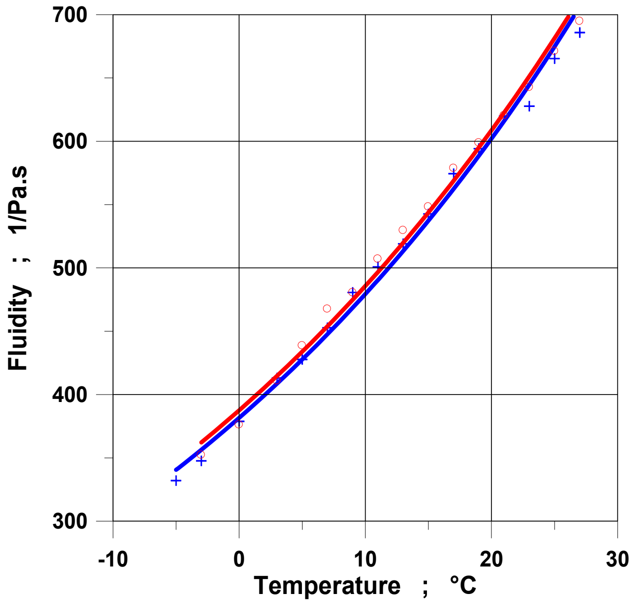

Figure 3
Temperature dependencies of whisky fluidity (Grant´s +, Jim Beam ○)

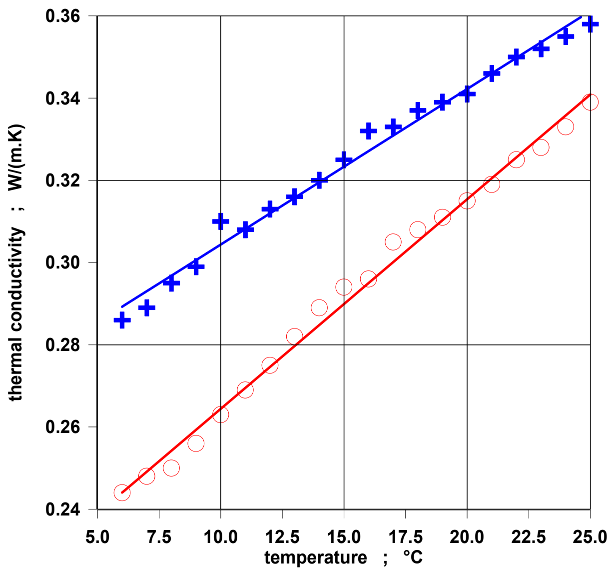

Figure 4
Temperature dependencies of whisky thermal conductivity (Grant´s +, Jim Beam ○)

Table 1. Coefficients A, B, C, D, E, F, G, H, I, J, K, L of regression equations (2, 3, 4, 5, 6, 7) and coefficients of determinations (R^2)

	Regression equations (2, 3, 4)			**Regression equations (5, 6, 7)**		
	Coefficients			**Coefficients**		
Whisky Sample	**A [mPa.s]**	**B [1]**	**R^2**	**G [$W.m^{-1}.K^{-1}$]**	**H [$W.m^{-1}.K^{-1}$]**	**R^2**
Grant's	2.6206	0.0228	0.9934	0.2134	0.0051	0.9927
Jim Beam	2.5838	0.0228	0.9919	0.2665	0.0038	0.9873
Whisky Sample	**C [$mm^2.s^{-1}$]**	**D [1]**	**R^2**	**I [$mm^2.s^{-1}$]**	**J [$mm^2.s^{-1}$]**	**R^2**
Grant's	2.7022	0.0220	0.9851	0.6052	0.0034	0.9469
Jim Beam	2.6766	0.0217	0.9876	0.6237	0.0038	0.9958
Whisky Sample	**E [$Pa^{-1}.s^{-1}$]**	**F [1]**	**R^2**	**K [$MJ.m^{-3}.K^{-1}$]**	**L [$MJ.m^{-3}.K^{-1}$]**	**R^2**
Grant's	381.585	0.0228	0.9934	0.4305	0.0029	0.9395
Jim Beam	387.529	0.0226	0.9917	0.3583	0.0055	0.9856

Temperature dependencies of thermal conductivity and diffusivity are shown on Fig. 4 and Fig. 5 and temperature dependencies of volume specific heat are on Fig. 6.

It can be seen from Fig. 4 that thermal conductivity of both whisky samples is increasing with temperature linearly. From Fig. 4 can be also seen that thermal conductivity of whisky Grant's is higher than values for whisky Jim Beam. Thermal diffusivity of whisky samples is increasing linearly with temperature (Fig. 5). Also in this case are values of thermal diffusivity of whisky Grant's higher than for whisky Jim Beam. Dependency of whisky volume specific heat on temperature is on Fig. 6. It is evident that volume specific heat of whisky samples is increasing linearly with temperature. Higher values of volume specific heat had whisky Grant's. Position of the curves in Fig. 4 – 6 could be caused by different quality of basic whisky ingredients, which influence final thermal parameters of whisky. All regression coefficients and coefficients of determination are shown in Tab. 1. In all cases were the coefficients of determination higher than 0.94 approximately.

CONCLUSIONS

Rheologic and thermal properties of two types of whisky were compared in this paper. Both types of whisky (Grant's and Jim Beam) have very similar rheologic properties. It can be seen on temperature dependencies of dynamic, kinematic viscosity and fluidity (Fig. 1 – 3), where increasing (respectively decreasing) exponential functions were applied and it is in accordance with Arrhenius equation. In all relations of thermal properties was used linear increasing function. It can be seen on Fig. 4 – 6 that whisky Grant's had higher values of thermal conductivity, diffusivity and volume specific heat than whisky Jim Beam. This proportion was caused by different types of basic ingredients or by small differences during the production. Results showed that temperature has significant influence on thermal and rheologic parameters.

Knowledge about physical properties of food products can be used at determination of their quality.

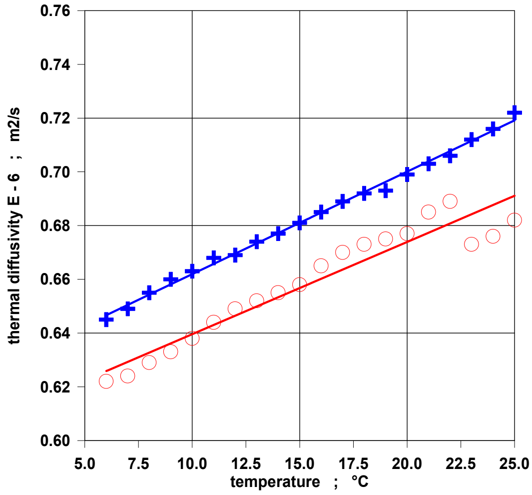

Figure 5
Temperature dependencies of whisky thermal diffusivity (Grant´s +, Jim Beam ○)

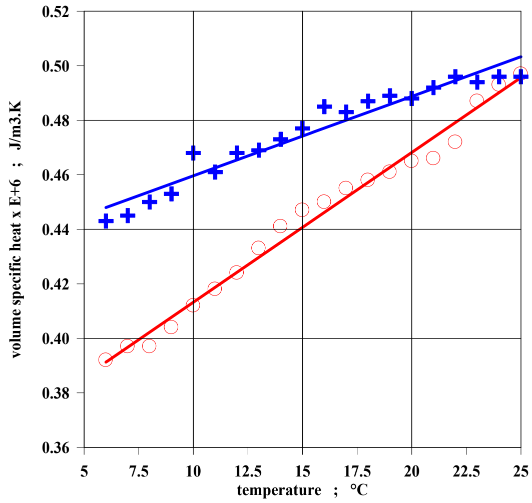

Figure 6
Temperature dependencies of whisky volume specific heat (Grant´s +, Jim Beam ○)

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