Influence of storing and temperature on rheologic and thermophysical properties of whisky samples

Vplyv skladovania a teploty na reologické a termofyzikálne vlastnosti vzoriek whisky

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Abstract

Temperature and storing time can be included between the most significant parameters that influence physical properties of food. This article deals with selected rheologic and thermophysical properties of alcohol drink whisky. Our research was oriented on measuring of rheologic and thermophysical characteristics of whisky. There were measured two types of whisky – Grant's and Jim Beam from two different producers, both samples had 40 % of alcohol content. During the experiments were analyzed rheologic parameters as: dynamic viscosity, kinematic viscosity and fluidity and thermophysical parameters as: thermal conductivity, thermal diffusivity and volume specific heat. Selected parameters were measured in temperature range (-5 – 27) °C. Measurements were done on whisky samples in different days during the storage. Measuring of dynamic viscosity was performed by digital rotational viscometer Anton Paar (DV-3P). Principle of measuring is based on dependency of sample resistance against the probe rotation. Density of whisky samples was determined by pycnometric method. Average density at given temperature along with dynamic viscosity value was used at calculation of kinematic viscosity and fluidity was also determined. Measuring of thermophysical 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. Relations of rheologic and thermophysical parameters to the temperature were made and influence of storing time was discussed. From obtained results is clear that dynamic and kinematic viscosity is decreasing exponentially with temperature and fluidity has increasing exponential progress. We found out that both whisky samples had at the beginning and after one week of storage very similar values of rheologic parameters. Very small difference in rheologic parameters of whisky samples was found after two weeks of storing. Values of dynamic and kinematic viscosity were a bit higher and values of fluidity were a bit smaller after storing, that can be caused by loosening of the water during storage. Thermophysical parameters are increasing linearly with temperature for both whisky samples. Higher values of thermophysical parameters were in all cases obtained for whisky Grant's.

Keywords: dynamic viscosity, fluidity, kinematic viscosity, storing time, temperature, thermal conductivity, thermal diffusivity, volume specific heat, whisky

Abstrakt

Teplota a doba skladovania patria medzi najdôležitejšie parametre, ktoré ovplyvňujú fyzikálne vlastnosti potravín. Tento príspevok sa zaoberá vybranými reologickými a termofyzikálnymi vlastnosťami alkoholického nápoja whisky. Náš výskum bol zameraný na meranie reologických a termofyzikálnych charakteristík whisky. Na meranie boli použité dva druhy whisky - Grant's a Jim Beam od rôznych producentov. Oba druhy whisky mali 40 % obsah alkoholu. Počas experimentov boli určované nasledovné reologické parametre: dynamická viskozita, kinematická viskozita a tekutosť a tiež termofyzikálne parametre ako: tepelná vodivosť, teplotná vodivosť a objemová tepelná kapacita. Vybrané fyzikálne vlastnosti boli merané v teplotnom intervale (-5 – 27) °C a meranie prebehlo v rôznych dňoch počas skladovania. Meranie dynamickej viskozity bolo uskutočnené pomocou digitálneho rotačného viskozimetra Anton Paar (DV-3P), pričom princíp merania je založený na závislosti odporu vzorky voči otáčaniu sondy. Hustota vzoriek bola určená pyknometrickou metódou. Priemerná hustota pri danej teplote spoločne s hodnotou dynamickej viskozity bola použitá pri stanovení kinematickej viskozity. Prevrátená hodnota dynamickej viskozity (tekutosť) bola tiež vypočítaná. Meranie termofyzikálnych parametrov bolo uskutočnené pomocou prístroja Isomet 2104, pričom meranie je založené na analýze teplotnej odozvy na tepelné impulzy aplikované do meraného materiálu. Zhotovili sme závislosti reologických a termofyzikálnych parametrov od teploty a rozobrali sme vplyv doby skladovania na uvedené vlastnosti. Zo získaných výsledkov je zrejmé, že dynamická a kinematická viskozita klesá s teplotou exponenciálne, zatiaľ čo tekutosť vzoriek s teplotou exponenciálne rastie. Ďalej je možné vidieť, že reologické parametre oboch vzoriek whisky boli na začiatku skladovania a aj po jednom týždni skladovania veľmi podobné. Veľmi malé rozdiely v reologických parametroch sa objavili po dvoch týždňoch skladovania. Hodnoty dynamickej a kinematickej viskozity boli o málo vyššie a hodnoty tekutosti boli o málo nižšie po skladovaní, čo môže byť spôsobené strácaním vody počas skladovania. Pre všetky termofyzikálne parametre a obe vzorky whisky bola zistená lineárne rastúca závislosť od teploty. Vo všetkých prípadoch vyšli hodnoty termofyzikálnych parametrov vyššie pre whisky Grant's.

Kľúčové slová: doba skladovania, dynamická viskozita, kinematická viskozita, objemová tepelná kapacita, tekutosť, tepelná vodivosť, teplota, teplotná vodivosť, whisky

Detailný abstrakt

Špecifické vlastnosti whisky sú závislé najmä od použitých ingrediencií vo výrobnom procese, použitom technologickom postupe spracovania. Ďalším významným faktorom ovplyvňujúcim konečnú kvalitu whisky je spôsob uskladnenia pri jej zretí a doba jej skladovania v špeciálnych nádobách určených na zretie whisky. Z vyššie uvedených dôvodov boli skúmané vybrané reologické a termofyzikálne vlastnosti dvoch druhov whisky (Grant´s a Jim Beam) od rôznych výrobcov v závislosti od teploty po jednom a dvoch týždňoch skladovania. Oba druhy whisky mali 40 %

obsah alkoholu. Počas experimentov boli určované nasledovné reologické parametre: dynamická viskozita, kinematická viskozita a tekutosť a tiež termofyzikálne parametre ako: tepelná vodivosť, teplotná vodivosť a objemová tepelná kapacita. Vybrané fyzikálne vlastnosti boli merané v teplotnom intervale (-5 – 27) °C a meranie prebehlo v rôznych dňoch počas skladovania. Meranie dynamickej viskozity bolo uskutočnené pomocou digitálneho rotačného viskozimetra Anton Paar (DV-3P), pričom princíp merania je založený na závislosti odporu vzorky voči otáčaniu sondy. Hustota vzoriek bola určená pyknometrickou metódou. Priemerná hustota pri danej teplote spoločne s hodnotou dynamickej viskozity bola použitá pri stanovení kinematickej viskozity. Prevrátená hodnota dynamickej viskozity (tekutosť) bola tiež vypočítaná. Meranie termofyzikálnych parametrov bolo uskutočnené pomocou prístroja Isomet 2104, pričom meranie je založené na analýze teplotnej odozvy na tepelné impulzy aplikované do meraného materiálu. Zhotovili sme závislosti reologických a termofyzikálnych parametrov od teploty a rozobrali sme vplyv doby skladovania na uvedené vlastnosti. Zo získaných výsledkov je zrejmé, že dynamická a kinematická viskozita klesá s teplotou exponenciálne, zatiaľ čo tekutosť vzoriek s teplotou exponenciálne rastie. Ďalej je možné vidieť, že reologické parametre oboch vzoriek whisky boli na začiatku skladovania a aj po jednom týždni skladovania veľmi podobné. Veľmi malé rozdiely v reologických parametroch sa objavili po dvoch týždňoch skladovania. Hodnoty dynamickej a kinematickej viskozity boli o málo vyššie a hodnoty tekutosti boli o málo nižšie po skladovaní, čo môže byť spôsobené strácaním vody počas skladovania. Pre všetky termofyzikálne parametre a obe vzorky whisky bola zistená lineárne rastúca závislosť od teploty.
Z prezentovaných závislostí je zrejmé, že whisky Grant´s vykazovala vo všetkých prípadoch vyššie hodnoty termofyzikálnych parametrov.
Na základe výsledkov prezentovaných v článku a faktov uvádzaných v literatúre je zrejmé, že teplota a doba skladovania patria vo všeobecnosti medzi najdôležitejšie parametre, ktoré ovplyvňujú fyzikálne vlastnosti potravín a preto je poznanie ich vplyvu na potravinárske materiály jednou zo základných úloh potravinárskeho výskumu.

Introduction

Automatically controlled processes at manufacturing, at handling and holding require exact knowledge about physical quantities of materials. In generally all food material during processing and storage goes through the thermal or mechanical manipulation, so it is convenient to know its physical properties such as electric, thermophysical and mechanical (especially rheologic for liquid materials) parameters. Some properties of whisky, mainly from the chemical point of view were analyzed by some authors. Reactive oxygen scavenging activity was evaluated by Koga et al. (2007). They found correlation between this activity and the maturation age of single malt whisky and also that non volatile fractions derived from the barrel were responsible for this activity. Changes in volatile sulphur compounds of whisky during aging were analyzed by Masuda and Nishimura (2006). Sensory characteristics of whisky sour samples were done by McDaniel and Sawyer (2006). Effects on whisky composition and flavour of maturation in oak casks with varying histories were studied by Piggot et al. (2007) and effect of cask charring on whisky maturation were examined by Clyne et al. (2007). 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 thermophysical. That is why our research was oriented on measuring of rheologic and thermophysical properties of whisky.

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). Finding some information about rheologic properties of whisky is almost impossible, and that is why this paper is focused on them.

Viscosity is one of the most important rheologic parameters and it can be defined as the resistance of a fluid to flow. The physical unit of dynamic viscosity in SI units is Pa.s. Due to the low viscosity values of liquids is more often used unit mPa.s. Viscosity of materials changes with the temperature. The difference in the effect of temperature on viscosity of fluids and gases can be related to the difference in their molecular structure. Viscosity of most of the liquids decreases with increasing of the temperature. The relation between viscosity and the temperature can be characterized by an Arrhenius type equation (1)

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

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). Liquid molecules are closely spaced with strong cohesive forces between them. The temperature dependence of viscosity can also be explained by cohesive forces between the molecules (Munson et al., 1994). As temperature increases, these cohesive forces between the molecules decrease and flow became freer. As a result viscosities of liquids decrease as temperature increases. In liquids, the intermolecular (cohesive) forces play an important role (Sahin and Sumnu, 2006).

Except of dynamic viscosity we can include into rheologic parameters other quantities such as kinematic viscosity and fluidity. Ratio of dynamic viscosity η to the density of fluid ρ at the same temperature is called kinematic viscosity v and it can be expressed by following equation

$$\nu = \frac{\eta}{\rho} \qquad (2)$$

Its physical unit in SI units is $m^2.s^{-1}$, but for liquid materials is usually used unit mm^2*s^{-1}. Fluidity φ is defined as reciprocal value of dynamic viscosity η and its physical unit is $Pa^{-}1*s^{-1}$.

$$\varphi = \frac{1}{\eta} \qquad (3)$$

Materials and Methods

Our research was oriented on measuring of rheologic and thermophysical characteristics of whisky. There were measured two types of whisky – Grant's and Jim Beam from two different producers. During the experiments were determined rheologic parameters as: dynamic viscosity, kinematic viscosity and fluidity and thermophysical parameters such as: thermal conductivity, thermal diffusivity and volume specific heat. Samples of whisky were stored in a cool box at temperature around 3 °C. Before each measuring were the samples cooled to temperatures below 0 °C (only few degrees) and measurements were performed in different days during storage. Measurements were usually performed in temperature interval from -5 °C to 27 °C during the temperature stabilization.

Measuring of dynamic viscosity was performed by digital viscometer Anton Paar (DV-3P). Principle of measuring by this viscometer is based on dependency of sample resistance against the probe rotation. Probe with signification R2 was used in our measurements. We have chosen frequency of probe rotation 200 min^{-1}. Density of whisky samples was determined by pycnometric method. Average density at given temperature along with dynamic viscosity value was used at calculation of kinematic viscosity. Relations of dynamic and kinematic viscosity to the temperature can be described by decreasing exponential functions (4, 5) and in the case of relations of fluidity to the temperature can be used increasing exponential function (6)

$$\eta = A e^{-B\left(\frac{t}{t_o}\right)} \qquad (4)$$

$$\nu = C e^{-D\left(\frac{t}{t_o}\right)} \qquad (5)$$

$$\varphi = E e^{F\left(\frac{t}{t_o}\right)} \qquad (6)$$

where t is temperature, t_o is 1 °C, A, B, C, D, E, F, are constants dependent on kind of material, and on ways of processing and storing. Influence of storage or storage time on physical properties of food materials was also examined.

Measuring of thermophysical parameters (thermal conductivity and thermal diffusivity) was performed by instrument Isomet 2104 which uses Hot wire method. Measurement by Isomet is based on analysis of the temperature response of the measured sample to heat flow impulses. Definitions of selected thermophysical parameters are explained in publication Božiková and Hlaváč (2010). Temperature dependencies of thermal conductivity, diffusivity and volume specific heat can be described by increasing linear functions (7, 8 and 9)

$$\lambda = G + H\left(\frac{t}{t_0}\right) \qquad (7)$$

$$a = I + J\left(\frac{t}{t_0}\right) \qquad (8)$$

$$c\rho = K + L\left(\frac{t}{t_0}\right) \quad (9)$$

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

Results and discussion

Dependencies of dynamic viscosity, kinematic viscosity, fluidity, thermal conductivity, diffusivity and volume specific on temperature were examined. Effect of storage was also investigated. Relations of dynamic viscosity to the temperature for both samples of whisky after one week and after two weeks of storing are presented on Fig. 1 and Fig. 2. It is possible to observe from Fig. 1 and Fig. 2 that dynamic viscosity of both whisky samples is decreasing with increasing of temperature. The progress can be described by decreasing exponential function, which is in accordance with Arrhenius equation (1). It is also evident that values of dynamic viscosity were similar for both samples after one week of storing (Fig. 1), but after two weeks of storing we can observe very small difference (Fig. 2).

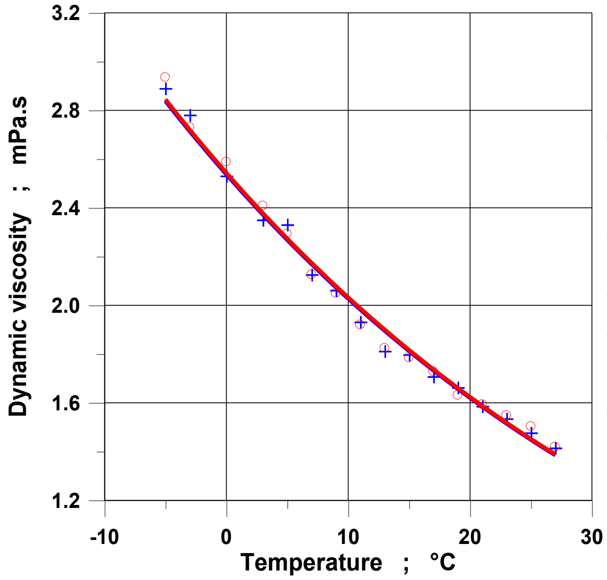


Figure 1 Relations of whisky dynamic viscosity to the temperature after one week of storing: Grant´s +, Jim Beam ○

Obrázok 1 Teplotná závislosť dynamickej viskoizity po týždňovom skladovaní pre whisky: Grant´s +, Jim Beam ○

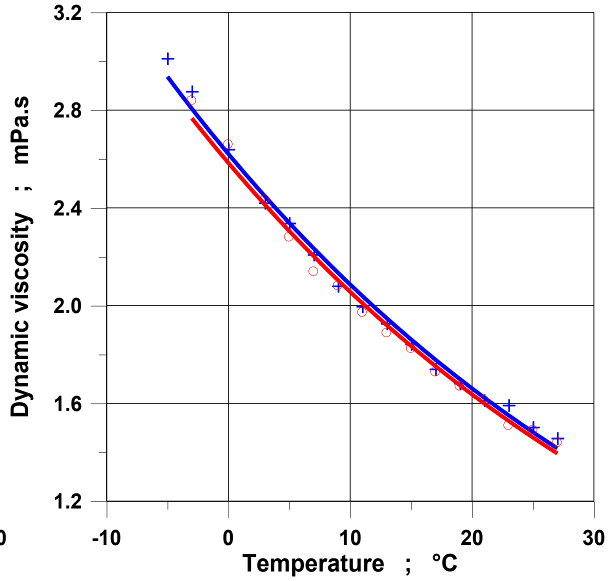


Figure 2 Relations of whisky dynamic viscosity to the temperature after two weeks of storing: Grant´s +, Jim Beam ○

Obrázok 2 Teplotná závislosť dynamickej viskoizity po dvojtýždňovom skladovaní pre whisky: Grant´s +, Jim Beam ○

Relations of kinematic viscosity and fluidity to the temperature for both whisky samples after one and two weeks of storing are presented on Fig. 3 – 6. The dependency of kinematic viscosity on temperature can be also described by decreasing exponential function (Fig. 3 and Fig. 4). From Fig. 4 we can observe even smaller difference in values of kinematic viscosity for both whisky samples after two weeks of storing.

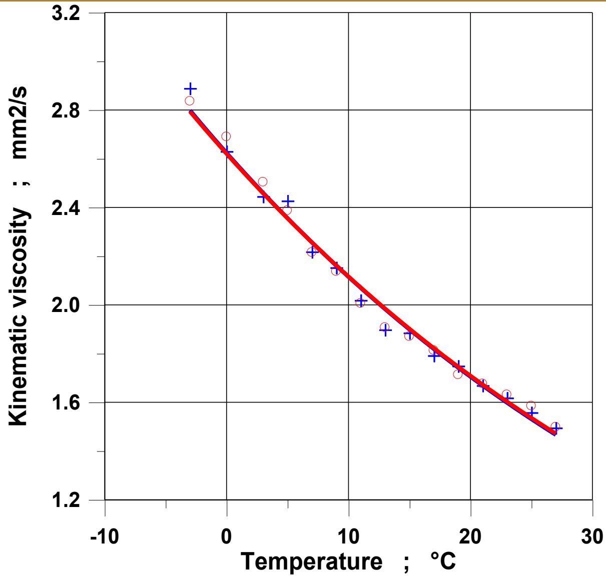


Figure 3 Relations of whisky kinematic viscosity to the temperature after one week of storing: Grant´s +, Jim Beam ○

Obrázok 3Teplotná závislosť kinematickej viskoizity po týždňovom skladovaní pre whisky: Grant´s +, Jim Beam ○

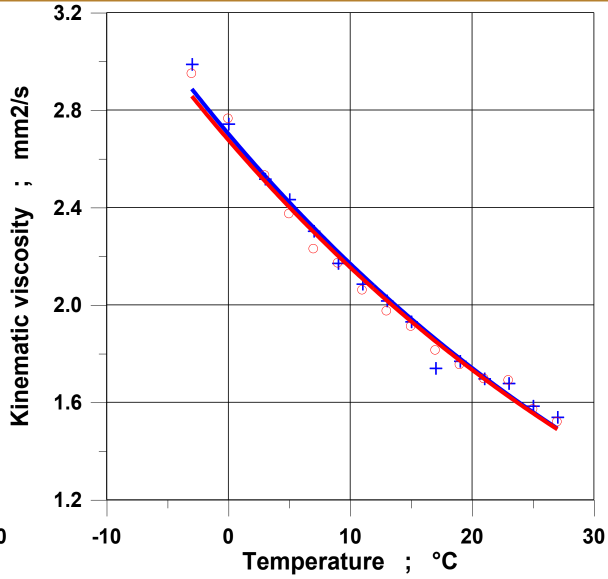
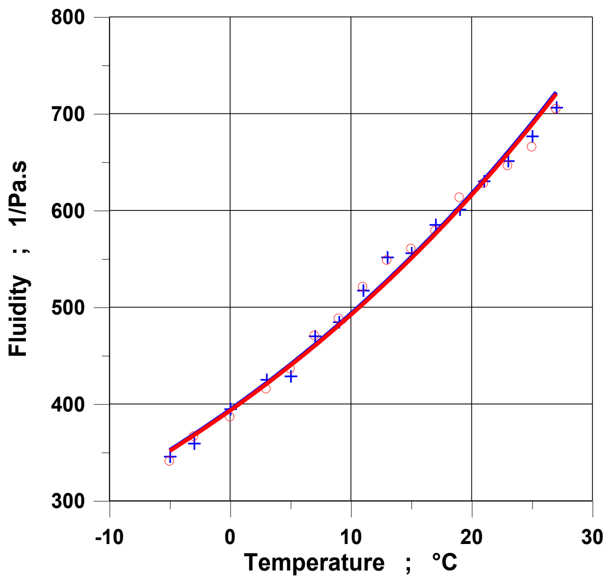


Figure 4 Relations of whisky kinematic viscosity to the temperature after two weeks of storing: Grant´s +, Jim Beam ○

Obrázok 4Teplotná závislosť kinematickej viskoizity po dvojtýždňovom skladovaní pre whisky: Grant´s +, Jim Beam ○

The temperature dependency of fluidity can be seen on Fig. 5 and Fig. 6. It is evident that fluidity is increasing with increasing of the temperature. Difference in fluidity values after one week of storing (Fig. 5) is not visible and it is very small after two weeks of storing (Figure 6). Effect of storing is more visible in graphs for one sample. On Fig. 7 – 9 are shown temperature dependencies of rheologic parameters for whisky sample Grant's and on Fig. 10 – 12 are shown temperature dependencies of rheologic parameters for whisky sample Jim Beam.



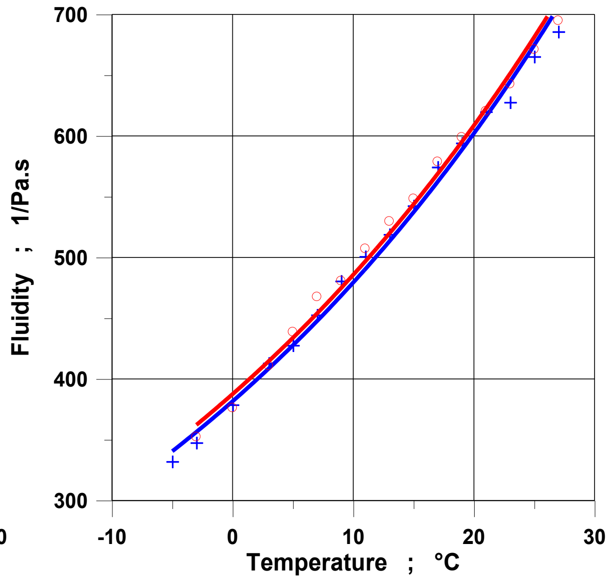


Figure 5 Relations of whisky fluidity to the temperature after one week of storing: Grant´s +, Jim Beam ○

Obrázok 5 Teplotná závislosť tekutosti po týždňovom skladovaní pre whisky: Grant´s +, Jim Beam ○

Figure 6 Relations of whisky fluidity to the temperature after two weeks of storing: Grant´s +, Jim Beam ○

Obrázok 6 Teplotná závislosť tekutosti po dvojtýždňovom skladovaní pre whisky: Grant´s +, Jim Beam ○

On Fig. 7 and Fig. 10 can be seen that dynamic viscosity of both whisky samples is decreasing exponentially with temperature and also that dynamic viscosity values are a bit higher after longer storage which is caused by loosening of the water during the storage. Same comparison may be done for kinematic viscosity (Fig. 8 and Fig. 11). In case of fluidity (Fig. 9 and Fig. 12) is clear that fluidity is increasing exponentially with the temperature and that fluidity values are a bit lower after longer storage which is caused by loosening of the water during the storage.

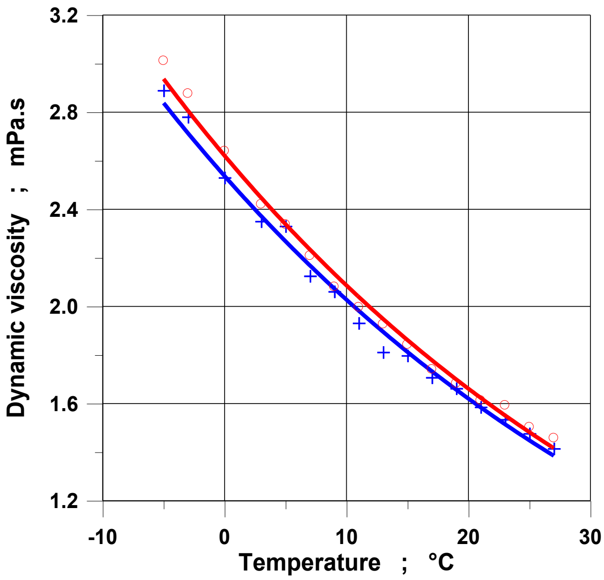


Figure 7 Relations of whisky Grant's dynamic viscosity to the temperature: after one week of storing +, after two weeks of storing ○

Obrázok 7 Teplotná závislosť dynamickej viskozity whisky Grant's: po týždňovom skladovaní +, po dvojtýždňovom skladovaní ○

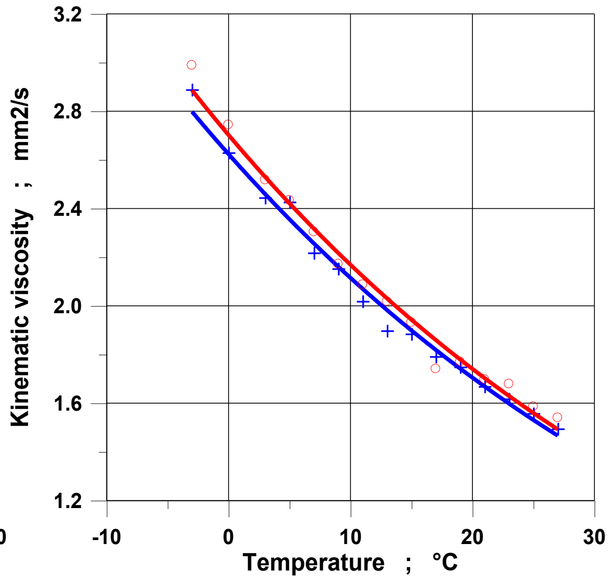


Figure 8 Relations of whisky Grant's kinematic viscosity to the temperature: after one week of storing +, after two weeks of storing ○

Obrázok 8 Teplotná závislosť kinematickej viskozity whisky Grant's: po týždňovom skladovaní +, po dvojtýždňovom skladovaní ○

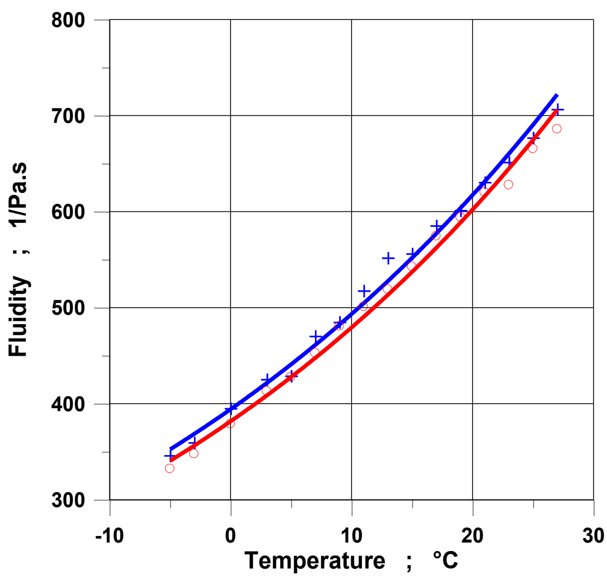


Figure 9 Relations of whisky Grant's fluidity to the temperature:
after one week of storing +,
after two weeks of storing ○

Obrázok 9 Teplotná závislosť tekutosti whisky Grant's:
po týždňovom skladovaní +,
po dvojtýždňovom skladovaní ○

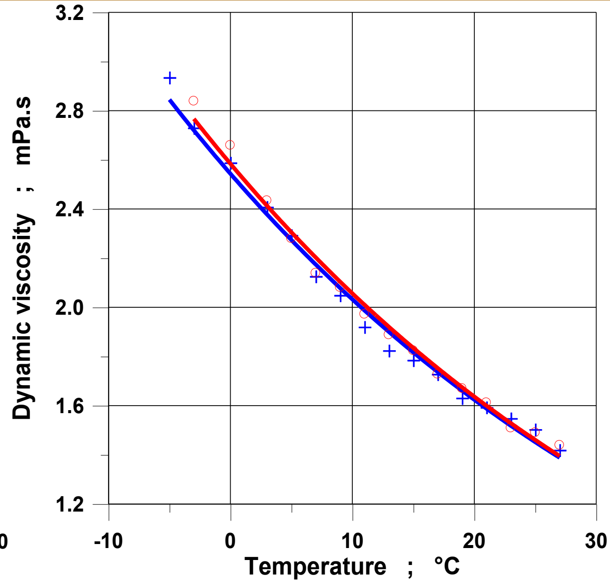


Figure 10 Relations of whisky Jim Beam dynamic viscosity to the temperature:
after one week of storing +,
after two weeks of storing ○

Obrázok 10 Teplotná závislosť dynamickej viskozity whisky Jim Beam:
po týždňovom skladovaní +,
po dvojtýždňovom skladovaní ○

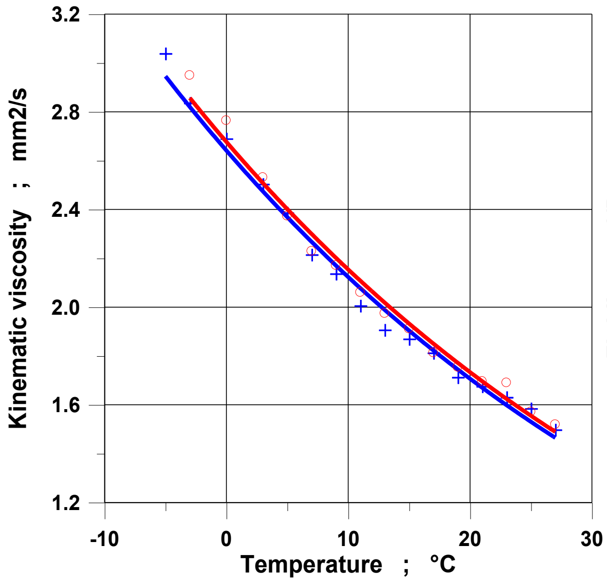


Figure 11 Relations of whisky Jim Beam kinematic viscosity to the temperature:
after one week of storing +,
after two weeks of storing ○

Obrázok 11 Teplotná závislosť kinematickej Viskozity whisky Jim Beam:

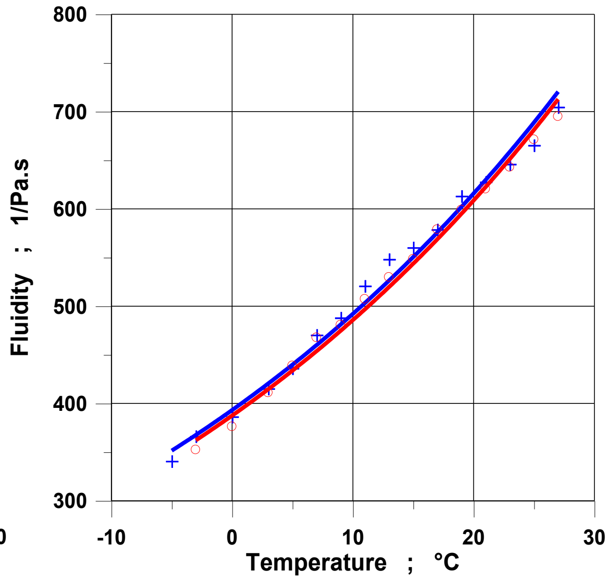


Figure 12 Relations of whisky Jim Beam fluidity to the temperature:
after one week of storing +,
after two weeks of storing ○

Obrázok 12 Teplotná závislosť tekutosti whisky Jim Beam:

po týždňovom skladovaní +, po týždňovom skladovaní +,
po dvojtýždňovom skladovaní ○ po dvojtýždňovom skladovaní ○

Differences in rheologic properties after one week and two weeks of storing were a bit higher for whisky Grant's than for whisky Jim Beam, so in our research whisky Jim Beam better preserved initial properties. All coefficients of regression equations and also coefficients of determination are presented in Tab. 1. In all cases were the coefficients of determination very high.

Table 1 Coefficients A, B, C, D, E, F of regression equation (4, 5, 6) and coefficients of determinations (R^2)

Tabuľka 1 Koeficienty A, B, C, D, E, F regresných rovníc (4, 5, 6) a koeficienty determinácie (R^2)

	Regression equations (4, 5, 6)		
	Coefficients		
Whisky Grant´s – storing	**A [mPa*s]**	**B [1]**	**R^2**
One week	2.536 96	0.022 423 6	0.991 856
Two weeks	2.620 64	0.022 799 1	0.993 365
Whisky Jim Beam – storing	**A [mPa*s]**	**B [1]**	**R^2**
One week	2.543 26	0.022 428 1	0.989 765
Two weeks	2.583 75	0.022 829 7	0.991 880
Whisky Grant´s – storing	**C [mm^2*s^{-1}]**	**D [1]**	**R^2**
One week	2.623 47	0.021 545 5	0.989 569
Two weeks	2.702 23	0.021 984 7	0.985 065
Whisky Jim Beam – storing	**C [mm^2*s^{-1}]**	**D [1]**	**R^2**
One week	2.641 29	0.021 834 8	0.988 782
Two weeks	2.676 63	0.021 722 3	0.987 579
Whisky Grant´s – storing	**E [$Pa^{-1}*s^{-1}$]**	**F [1]**	**R^2**
One week	394.173	0.022 423 6	0.991 857
Two weeks	381.585	0.022 799 2	0.993 365
Whisky Jim Beam – storing	**E [$Pa^{-1}*s^{-1}$]**	**F [1]**	**R^2**
One week	393.196	0.022 428 1	0.989 766
Two weeks	387.529	0.022 570 2	0.991 668

Temperature dependencies of thermal conductivity and diffusivity are shown on Fig. 13 and Fig. 14 and temperature dependencies of volume specific heat are shown on Fig. 15.

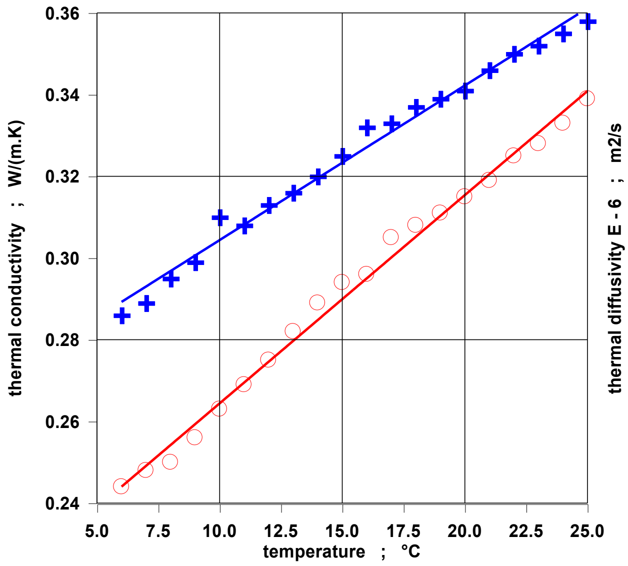


Figure 13 Temperature dependencies whisky thermal conductivity (Grant´s +, Jim Beam ○)

Obrázok 13 Závislosti tepelnej vodivosti od teploty pre whisky: (Grant´s +, Jim Beam ○)

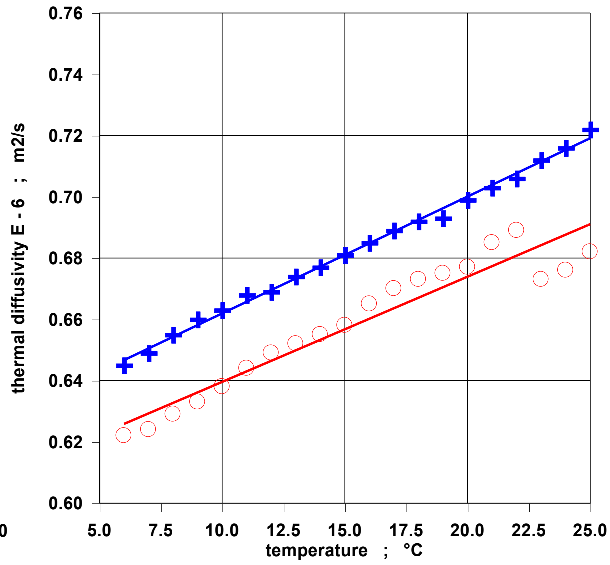


Figure 14 Temperature dependencies of whisky thermal diffusivity (Grant´s +, Jim Beam ○)

Obrázok 14 Závislosti teplotnej vodivosti od teploty pre whisky: (Grant´s +, Jim Beam ○)

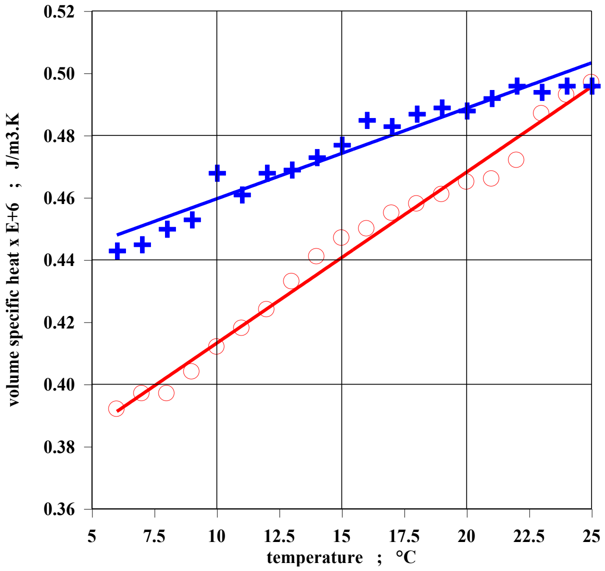


Figure 15 Temperature dependencies of whisky volume specific heat (Grant´s +, Jim Beam ○)

Obrázok 15 Závislosť objemovej tepelnej kapacity od teploty pre whisky (Grant´s +, Jim Beam ○)

It can be seen from Fig. 13 that thermal conductivity of both whisky samples is increasing with temperature linearly. From Fig. 13 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. 14). 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. 15. 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. 13 – 15 could be caused by different quality of basic ingredients, which influence final thermophysical properties of whisky. All regression coefficients and coefficients of determination are shown in Tab. 2. In all cases were the coefficients of determination higher than 0.94 approximately.

Table 2 Coefficients G, H, I, J, K, L of regression equations (7, 8, 9) and coefficients of determinations (R^2)

Tabuľka 2 Koeficienty G, H, I, J, K, L regresných rovníc (7, 8, 9) a koeficienty determinácie (R^2)

	Regression equations (7, 8, 9)		
	Coefficients		
Whisky Sample	**G [W*m^{-1}*K^{-1}]**	**H [W*m^{-1}*K^{-1}]**	**R^2**
Grant's	0.2134	0.0051	0.9927
Jim Beam	0.2665	0.0038	0.9873
Whisky Sample	**I [mm^2*s^{-1}]**	**J [mm^2*s^{-1}]**	**R^2**
Grant's	0.6052	0.0034	0.9469
Jim Beam	0.6237	0.0038	0.9958
Whisky Sample	**K [MJ*m^{-3}*K^{-1}]**	**L [MJ*m^{-3}*K^{-1}]**	**R^2**
Grant's	0.4305	0.0029	0.9395
Jim Beam	0.3583	0.0055	0.9856

Conclusions

Particular properties of whiskies depend mostly on the ingredients used during the production, on the used production method, and also way and time of maturing in special containers (wood barrels). Rheologic properties of two whisky samples were measured and analyzed in this paper. Effect of temperature and also effect of storage time on used whisky sample was searched. Dynamic viscosity of the sample was measured by digital viscometer Anton Paar DV-3P. Temperature dependencies of both whisky samples dynamic and kinematic viscosity had decreasing exponential shape (Fig. 1 – 4, Fig. 7 – 8 and Fig. 10 – 11) and temperature dependencies of fluidity had increasing exponential shape for all measurements (Fig. 5 – 6, Fig. 9 and Fig. 12). The coefficients of determination are very high in all measurements, approximately in the range (0.985 – 0.993) (Tab. 1). Arrhenius equation (1) has decreasing exponential shape, so the dependency of dynamic viscosity on temperature can be described by it. Obtained results could not be compared with other sources due to the fact that it is impossible to find any papers corresponding with rheologic properties of whisky. It can be seen from Fig. 7 – 8 and Fig. 10 – 11 that dynamic and kinematic viscosity values were a bit higher after storing due to loosening of the water during storage. Values of fluidity (Fig. 9 and Fig. 12) were a bit smaller after storing, which is caused by loosening of the water during the storage. Differences in rheologic properties after one week and two weeks of storing were a bit higher for whisky sample Grant's than for whisky sample Jim Beam. In our research whisky sample Jim Beam proved better preservation of initial properties. Effect of storage on food materials is very important and it was examined by many authors, for example Božiková and Hlaváč (2010), Kubík (2006), Hlaváč (2008, 2010), Hlaváč and Božiková (2011). In all relations of thermal properties was used linear increasing function. It can be seen on Fig. 13 – 15 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.

On the base of presented results from rheologic and thermophysical parameters measurements is clear that it is necessary to have knowledge about physical parameters during temperature changes, because temperature is one of the most important factors which determine quality of food materials.

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