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INFLUENCE OF THE SELECTED FACTORS ON THE LIQUID FOOD DENSITY

UTICAJ ODABRANIH FAKTORA NA GUSTINU TEČNE HRANE

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ABSTRACT

The density of materials can be used for assessing their quality. The density of food materials depends on temperature and is caused by thermal expansion during heating. The density of a material is defined as a ratio between the mass of the material and its volume at the same temperature. One of the most exact methods for measuring liquid density is the pycnometric method. Measurements of materials density could also be performed using hydrometers or densimeters, where the exact value of density can be discerned on the hydrometer scale or on the display of measurement devices. During our experiments, we used two methods of density determination: pycnometric method and determination by a densimeter Mettler Toledo DM 40. Measurements were performed in the approximate temperature range (0 – 30) °C. The effect of various parameters (such as temperature, fat content, alcohol content and short storing time) on the density of the material was analysed in this paper. A linear decreasing character was applied for temperature dependencies of the sample density in the measured temperature range. The highest fat content of milk caused the lowest density, whereas lower fat contents (less than 1.5 %) were not consistent with this proportion due to different amounts of proteins in the measured samples of milk. The effect of the alcohol content on density had to be investigated alongside the material composition (wine, whisky and piña colada). The density values obtained were a bit higher after a short storage period due to the water loss during storage.

Key words: *density, measurement, liquid food, affecting factors,*

REZIME

Gustina materijala može se koristiti za procenu njegovog kvaliteta. Gustina prehrambenih materijala zavisi od temperature i izazvana je toplotnom ekspanzijom tokom zagrevanja. Gustina materijala je definisana kao odnos mase materijala i zapremina pri istoj temperaturi. Jedna od najtačnijih metoda merenja tečnosti je piknometrijska metoda. Merenje gustine materijala, takođe, može se obaviti pomoću hidrometara ili densimetara , pri čemu se tačna vrednost gustine može očitati na skali hidrometra ili na displeju mernih uređaja. Tokom eksperimenata korišćene su dve metode određivanja gustine: piknometrijska metoda i određivanje denzimetarom Mettler Toledo DM 40. Merenja su obavljena u približnom temperaturnom opsegu (0 - 30) °C. U radu je analiziran efekat različitih parametara (kao što su temperatura tečnosti, sadržaj masti, sadržaj alkohola i kratko vreme čuvanja) na gustinu materijala. Linearno smanjenje karaktera je primenjeno za zavisnost gustine od temperature u mernom opsegu temperature. Najveći sadržaj masnoće u mleku uzrokovao je najmanju gustinu, dok sadržaj masnoće (manje od 1,5%) nije bio u skladu sa ovim sadržajem, zbog različitih količina proteina u izmerenim uzorcima mleka . Efekat sadržaja alkohola na gustinu moraose ispitati uz sastav materijala (vino, viski i pina kolada). Dobijene vrednosti gustine su bile malo veće nakon kratkog vremena skladištenja usled gubitka vode tokom skladištenja.

Ključne reči: *gustina, merenje, tečna hrana, uticajni faktori.*

INTRODUCTION

Controlled production processes such as handling and holding require an exact knowledge of the physical quantities of materials. For the quality evaluation of food materials, the following physical properties are of pivotal importance: mechanical (*Kubík and Doležajová, 2014*; *Kubík et al., 2017*), rheologic (*Hlaváč and Božiková, 2011, 2012*; *Bikić et al., 2012*; *Bukurov et al., 2012*; *Glicerina et al., 2013*; *Diósi et al., 2014*) and thermophysical (*Božiková and Hlaváč, 2010*; *Glicerina et al., 2013*; *Micić et al., 2014*) properties. The density of foods is an important physical property, which depends on the structural properties of foods. (*Kelkar et al., 2015*). The quality of materials can be evaluated by the material's density. The density of food materials plays an important role in many processes such as separation, pneumatic and hydraulic transport, determination of the power required for pumping, and etc. (*Sahin and Sumnu, 2006*). The density of the material ρ is defined as a ratio between the mass of the material m and its volume V The definition is valid for solids, liquids, gases and disperses (*Figura and Teixeira, 2007*). The standard SI unit of density is $kg \cdot m^{-3}$.

$$\rho = \frac{m}{V} \tag{1}$$

The density of most solids and liquids can be calculated using Eq. 1. The accuracy of this method depends on the precision of mass and volume determination. One of the most exact methods for measuring liquid density is the pycnometric method. A pycnometer is a closable glass jar with a specified volume. Upon filling with measured liquid material, the pycnometer is closed. All air bubbles must be removed before closing. The pycnometer with the sample is weighed and the density of the material can be calculated using Equation 1. Wide-mouthed bottles can be used for very viscous materials such as tomato paste, butter and honey (*Sahin and Sumnu, 2006*). The density of liquid materials can be also measured. Densimeters (hydrometers) can be used for the density measurement of liquids. Liquid density can be measured by placing a hydrometer in a beaker filled with the liquid material. A hydrometer has a stem that extends from a tubular-shaped bulb. The diameter of the stem is approximately equal to the diameter of a thermometer. The bulb may be filled with a dense material to give it an appropriate weight so that the whole hydrometer sinks in the test liquid to such a depth that the upper stem is partly above the liquid. The depth to which the hydrometer sinks depends on the density of the fluid displaced. The deeper the hydrometer sinks, the lower the density of the liquid. The constant weight hydrometer works on the principle that a floating body displaces its own weight of fluid. Density hydrometers are sometimes prepared for a narrow range of measurement, and thus are sensitive to small changes in density. Specific names are given to these kinds of hydrometers such as lactometers for milk and oleometers for oil. The Twaddell hydrometer is used for liquids denser than water. The Baume scale consists of two scales, one of which is used for fluids heavier than water and the other for fluids lighter than water. A variety of hydrometers are also available for specific purposes other than density such as brix saccharometers for the percentage of sucrose by weight in a solution, alcoholmeters for the percentage of alcohol by volume, and others (*Sahin and Sumnu, 2006*). A piezoelectric-excited membrane device for quick measurements of liquid density and viscosity was presented by *Lu et al.* (*2017*). *Chen et al.* (*2014*) made predictions of density, viscosity and conductivity of the ternary aqueous solutions of piperidinium-based ionic liquids at different temperatures and atmospheric pressure using the data of their binary subsystems.

Density is often used for the determination of other physical properties (rheologic, thermal, etc.) There are several measurement techniques for density that involve a separate determination of the mass and volume of the food sample (*Kelkar et al., 2015*). *Barbosa* (*2003*) and *Barbosa et al.* (*2003*) used ultrasonic measurements to measure densities of sucrose, glucose and citric acid solutions at temperatures between 10 °C and 30 °C and pressures up to 600 MPa. *Eder and Delgado* (*2007*) used optical refractive index measurements to determine the density of sodium chloride and sucrose solutions at pressures up to 500 MPa at 20 °C. The pycnometric method was used by *Min et al.* (*2010*) for determining the density of sucrose solutions, soy protein solutions, soybean oil, chicken fat, clarified butter, apple juice and honey. These authors report that the densities of the samples analyzed were increasing with increasing pressures. Densities of demineralised water and water-maltose-ethanol mixtures were investigated by *Hoche et al.* (*2015*) using the reflection method in the temperature range of 10 – 30 °C. The densities of measured samples were decreasing with a temperature increase. The densities of selected porous (breads and cookies) and non-porous food materials (tomato paste, mayonnaise and soybean oil) were determined by *Kelkar et al.* (*2015*) using X-ray imaging. Densities of porous materials were also determined by conventional techniques (mass and volume measurements) and densities of non-porous materials were also determined by pycnometric measurements. Authors claim that the results obtained using both techniques were comparable (*Kelkar et al., 2015*). A system of density measurements of liquid flowing in a pipeline based on quasi-hydrostatic measurements was presented by *Remiorz and Ostrowski* (*2015*). The densities of ternary aqueous solutions of piperidinium-based ionic liquids were measured by *Chen et al.* (*2014*) using an automatic U-tube densimeter at atmospheric pressure. The effect of temperature and composition on the bovine milk density was investigated by *Alcantara* (*2012*). A regression model of ultrafiltration milk concentrates was analysed by *Dinkov et al.* (*2008*). A comparison of the cow´s milk and soymilk densities was performed by *Oguntunde and Akintoye* (*1991*).

As density is influenced by many factors, the effects of various parameters (such as temperature, fat and alcohol content and short storing) on the material's density were analysed in this article.

Nomenclature:

m (kg)	- mass of the material
V (m^3)	- volume of the material*t* (°C)- temperature of the material analyzed
t_0 (°C)	- compared temperature of the material

Greek symbol

ρ ($kg\cdot m^{-3}$)	- density of the material

MATERIAL AND METHOD

During our experiments, two methods of density determination were used: pycnometric method and determination using a densimeter Mettler Toledo DM 40 (which contains an internal Peltier thermostat for automatic temperature control and therefore does not require an external thermostatic bath circulator). The values of density are shown on the measuring device display at each measured temperature. When the pycnometric method was used, the measurements were repeated three times and the average values were calculated. The pycnometer mass with the samples were weighed at each temperature with a precision of ± 0.0001 g. Our measurements were performed in the approximate temperature range (0 – 30) °C. Thr effect of various parameters (such as temperature, fat content, alcohol content and short storing time – one or two weeks) on the selected material density was examined. A linear decreasing character (Eq. 2) was applied for the temperature dependencies of the sample density in the measured temperature range.

$$\rho = A - B\left(\frac{t}{t_0}\right) \tag{2}$$

where *A* and *B* are the constants dependent on material types and methods of processing and storing, *t* is the temperature of the material analyzed, and the compared temperature of the material t_0 = 1 °C.

Measurements were performed on eight samples of liquid food materials purchased in local markets: white wine (Rizling Vlašský), red wine (Frankovka Modrá), two types of whisky (Jim Beam and Grant´s), piña colada and three types of milk with different fat contents.

RESULTS AND DISCUSSION

The results obtained are presented as the temperature dependencies of material density (Fig. 1 – 6). In this temperature range, a linear decreasing function was used. The same type of dependency was used also by other authors (*Tanilgan et al., 2007*; *Thomas et al., 2015; Emberger et al., 2015*; *San José et al., 2015*). All the regression coefficients and coefficients of determination are presented in Table 1. Figs. 1 and 2 display the dependencies of the wine density on temperature. Measurements were repeated after one week of storage for white wine. It can be seen (Fig. 1) that the values of white wine density were a bit higher after a short storage period due to the water loss during storage. The measurements of the red wine density were repeated after one week of storage, and also after two weeks of storage (Fig. 2). The density values obtained were also higher after storage so the same proportion of curves were obtained after one week and after two weeks of storage (as for white wine).

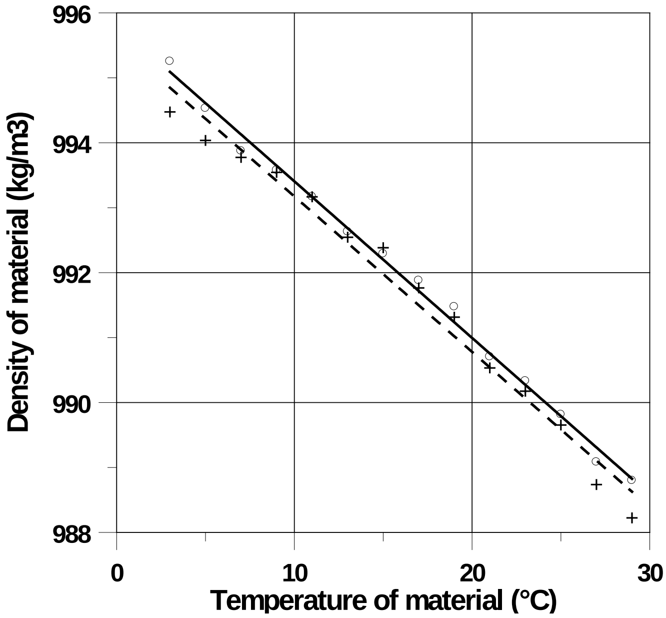

Fig. 1. Temperature dependencies of the white wine density first measurement (+), next measurement (○)

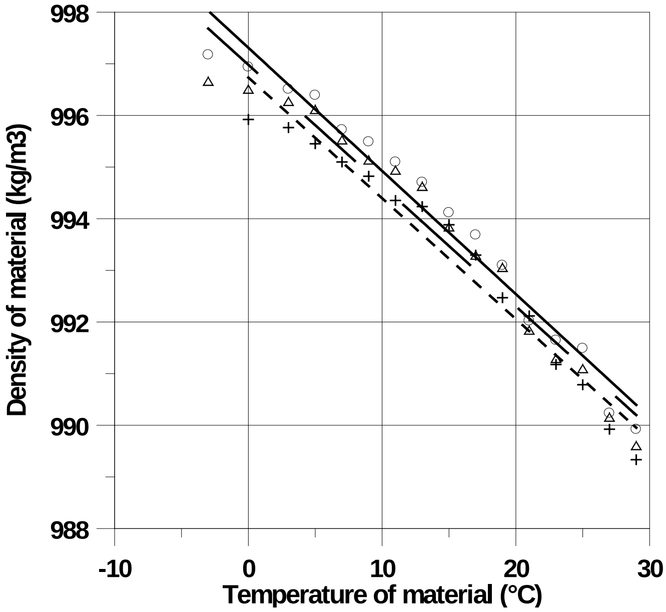

Fig. 2. Temperature dependencies of the red wine density first measurement (+), second measurement (Δ),next measurement (○)

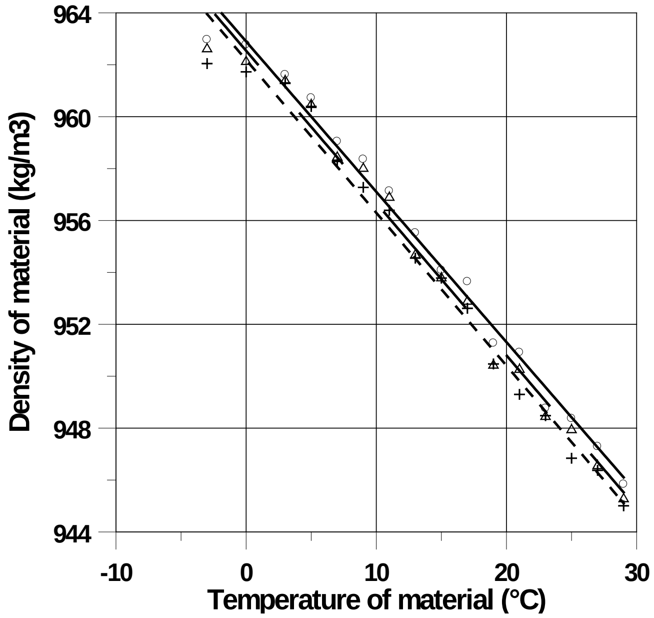

Fig. 3. Temperature dependencies of the whisky (Grant´s) density first measurement (+), second measurement (Δ), next measurement (○)

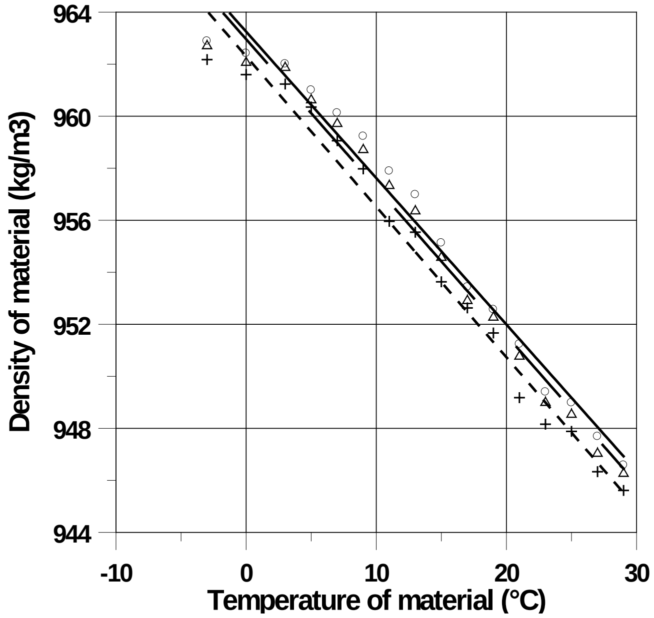

Fig. 4. Temperature dependencies of the whisky (Jim Beam) density first measurement (+), second measurement (Δ), next measurement (○)

The dependencies of the whisky densities on temperature are presented in Figs. 3 – 4. Similar results were obtained for both types of whisky. The densities obtained were a bit higher after one week of storage and even higher after two weeks of storage. The density measurements of piña colada were performed at the beginning of storage and after one week of storage (Fig. 5). It can be seen that the density values were higher after storing.

The effect of the alcohol content on density was investigated alongside the material composition (wine, whisky, piña colada). Wine with an alcohol content of approximately 10 % exhibited higher densities than the whisky samples with an alcohol content of 40 %. However, the densities of piña colada with an alcohol content of 16 % were higher than the densities of other alcohol drinks, which is caused by its composition. Changes in density can also be caused by the evaporation of alcohol during heating and storage.

Fig. 6 shows the dependencies of density on temperature for milks with different fat content. The highest fat content of milk caused the lowest density, but lower fat contents (less than 1.5 %) were not consistent with this proportion.

This could be due to different amounts of proteins in the measured milk samples. Similar values and a decreasing trend in milk density with increasing temperatures were observed by other authors (*Oguntunde and Akintoye, 1991*; *Dinkov et al., 2008*; *Alcantara, 2012*; *Kumbár and Nedomová, 2015*).

It can be seen from Tab. 1 that the coefficients of determination reached very high values in the approximate range (0.96 – 0.99).

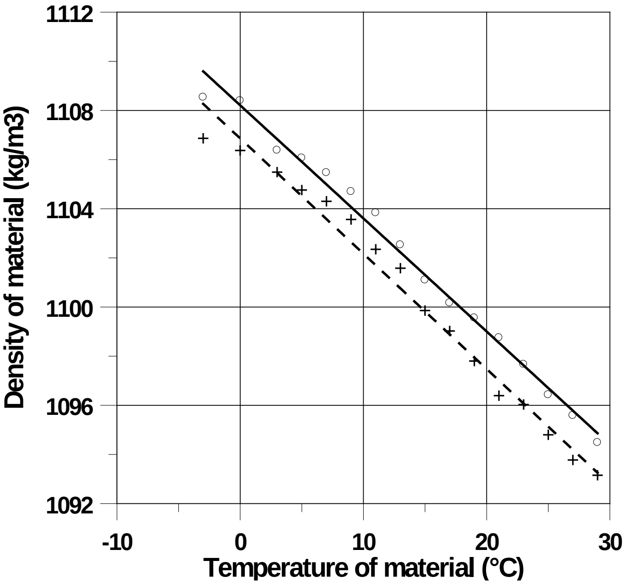

Fig. 5. Temperature dependencies of the piña colada density first measurement (+), next measurement (○)

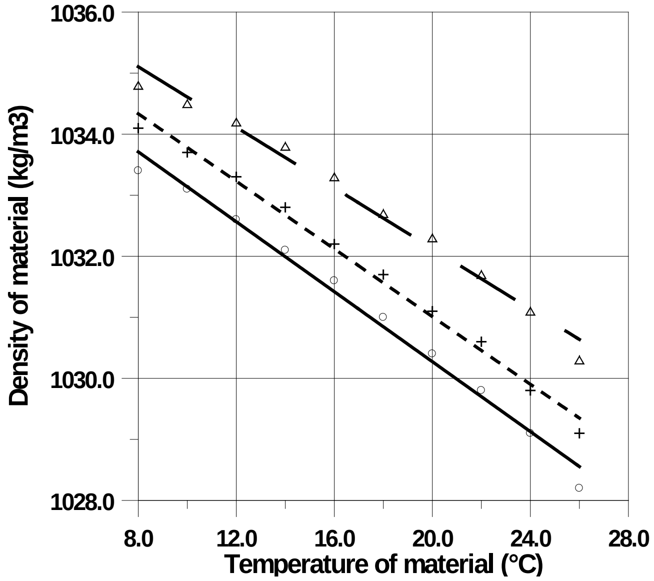

Fig. 6 Temperature dependencies of the milk density with fat contents (+) 0.5 %; (Δ) 1.5 %; (○) 3.5 %

Table 1. Coefficients A, B of the regression equation (2) and coefficients of determinations (R^2)

	Regression equation (2)		
	Coefficients		
Sample (measurement)	A [kg·m^{-3}]	B [kg·m^{-3}]	R^2
Piña colada (first)	1 106.86	0.469 087	0.983 177
Piña colada (next)	1 108.21	0.460 286	0.990 478
White wine (first)	995.566	0.239 273	0.981 496
White wine (next)	995.815	0.240 978	0.995 244
Red wine (first)	996.724	0.233 637	0.959 312
Red wine (second)	996.998	0.233 877	0.958 711
Red wine (next)	997.248	0.236 864	0.969 206
Whisky Grant´s (first)	962.187	0.588 991	0.984 428
Whisky Grant´s (second)	962.539	0.586 741	0.986 502
Whisky Grant´s (next)	962.897	0.579 167	0.987 977
Whisky Jim Beam (first)	962.305	0.578 705	0.981 369
Whisky Jim Beam (second)	962.960	0.569 368	0.981 292
Whisky Jim Beam (next)	963. 251	0.562 989	0.978 113
Milk (fat content 0.5 %)	1 036.55	0.276 969	0.991 812
Milk (fat content 1.5 %)	1037.09	0.248 183	0.983 792
Milk (fat content 3.5 %)	1036.00	0.286 364	0.988 326

CONCLUSION

The influence of various factors on the liquid food material density was investigated in this paper. The effect of temperature, fat content, alcohol content and short-term storage on density was examined on eight liquid food materials such as white and red wine, two types of whisky, piña colada and three types of milk with different fat contents. All the measurements were performed in the approximate temperature range (0 – 30) °C. The temperature dependencies of all the measured samples densities are characterized by a decreasing linear function in this temperature range, which is in accordance with other authors (*Oguntunde and Akintoye, 1991*; *Sahin and Sumnu, 2006*; *Figura and Teixeira, 2007*; *Dinkov et al., 2008*; *Alcantara, 2012*; *Kumbár and Nedomová, 2015*). The highest fat content of milk (3.5 %) caused the lowest density, but lower fat contents (less than 1.5 %) were not consistent with this proportion. This could be due to different amounts of proteins in the measured milk samples. The effect of the alcohol content on density was investigated alongside the material composition (wine, whisky and piña colada). The lowest density of all the alcohol drinks analyzed was recorded in both types of whisky, and their alcohol content was highest (40 %). Wines with a lower alcohol content (around 10 %) had higher densities. However, the density of piña colada with an alcohol content of 16 % was higher than the density of other alcohol drinks, which is caused by its composition. The alcohol content can also change due to the evaporation during heating and storage. The density sample values were a bit higher after short storage period due to the water loss during storage. An exact knowledge of the physical properties of liquid food products can be used for determining their quality.

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