Liquid Food Density Affected by Selected Factors

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Abstract. Density of materials can be used in assessing of material's quality. Density of food materials depends on temperature. It is caused by thermal expansion during heating. Density of material is defined as a ratio between mass of material and its volume at the same temperature. One of the most exact methods for measurement of liquid density is pycnometric method, which is based on definition. Measurements of materials density could be also performed by hydrometers or densimeters, where exact value of density can be found on the hydrometer´s scale or on the display of measurement device. During our experiments we used two methods of density determination: pycnometric method and determination by densimeter Mettler Toledo DM 40. Our measurements were performed in approximate temperature range (0 – 30) °C. Effect of various parameters (such as temperature, fat content, alcohol content and short storing time) on material's density is analysed in this article. Linear decreasing character was applied for temperature dependencies of density for all samples in measured temperature range. The highest fat content of milk had caused the lowest density, but lower fat contents (less than 1.5 %) does not proved this proportion due to the different amount of proteins in measured samples of milk. Effect of alcohol content on density had to be investigated together with material composition (wine, whisky, pinacolada). Values of density were a bit higher after short storing due to the loosening of water during the storage.

Keywords:

density,
liquid food,
measurement,
influencing factors,
dependence

INTRODUCTION

Density of foods is an important physical property, which depends on structural properties of foods. (Kelkar et al., 2015). The quality of materials can be evaluated by material's density. Density of food materials is needed in many areas, for example in separation processes, pneumatic and hydraulic transports, determination of the power required for pumping etc. (Sahin and Sumnu, 2006). Density of material ρ is defined as a ratio between mass of material m and its volume V

$$\rho = \frac{m}{V} \qquad (1)$$

The definition is valid for solids, liquids, gases and disperses (Figura and Teixeira, 2007). The standard SI unit of density is $kg \cdot m^{-3}$. Density of most solids and liquids can be calculated using Eq. (1). The accuracy of this method depends on precision of mass and volume determination. One of the most exact methods for measurement of liquid density is pycnometric method. Pycnometer is a closable glass jar with specified volume. Measured liquid material is filled into the pycnometer and after it the pycnometer is closed. All air bubbles must be removed before closing of the pycnometer. Pycnometer with the sample is weighted and the density of material can be calculated using equation (1). Wide – mouthed bottles can be used for very viscous materials such as tomato paste, butter, or honey (Sahin and Sumnu, 2006). Density of liquid materials can be also measured. For the density measurement of liquids could be used densimeters (hydrometers). Liquid density can be measured by placing a hydrometer in a beaker filled with the liquid material. The hydrometer has a stem that extends from tubular shaped bulb. The diameter of the stem is approximately equal to the diameter of 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 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 narrow range of measurement and therefore 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 has two scales, one of which is for fluids heavier than water and the other one is for lighter fluids. A variety of hydrometers are also available for specific purposes other than density such as brix saccharometers for percentage of sucrose by weight in solution, alcoholmeters for percentage of alcohol by volume, and others (Sahin and Sumnu, 2006).

Density is often used for determination of other physical properties (rheologic, thermal, etc.) There are several measurement techniques for density that involve separately determining 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 temperature between 10 °C and 30 °C and pressures up to 600 MPa. Eder and Delgado (2007) used optical refractive index measurement to determine density of sodium chloride and sucrose solutions at pressures up to 500 MPa at 20 °C. Pycnometric method was used by Min et al. (2010) for determination of density for sucrose solutions, soy protein solutions, soybean oil, chicken fat, clarified butter, apple juice and honey. Authors find out that densities of analysed samples were increasing with increasing pressure. Densities of demineralised water and water-maltose-ethanol mixtures were investigated by Hoche et al. (2015) using reflection method in temperature range (10 – 30) °C. Densities of measured samples were decreasing with temperature increase. 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 traditional technique (mass and volume measurement) and densities of non-porous materials were also determined by pycnometric measurement. Authors had claimed that obtained results by both techniques were comparable (Kelkar et al., 2015). System of density measurement of liquid flowing in a pipeline based on quasi-hydrostatic measurement was presented by Remiorz and Ostrowski (2015). Densities of ternary aqueous solutions of piperidinium-based ionic liquids were measured by Chen et al. (2014) using automatic U-tube densimeter at atmospheric pressure. Effect of temperature and composition on bovine milk density was investigated by Alcantara (2012). Regression model of ultrafiltration milk concentrates were analysed by Dinkov et al. (2008). Comparison of cow´s milk and soymilk density were performed by Oguntunde and Akintoye (1991).

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

MATERIALS AND METHODS

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

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

where A and B are constants dependent on kind of material, and on ways of processing and storing, t is temperature and $t_0 = 1$ °C.

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

RESULTS AND DISCUSSION

Results are presented as temperature dependencies of material density (Fig. 1 – 6). Linear decreasing progress was applied for all samples in measured temperature range. All regression coefficients and coefficients of determination are presented in Table. 1.

On Figs. 1 – 2 are presented dependencies of wine density on temperature. Measurements were repeated after one week of storing for white wine. It can be seen (Fig. 1) that values of white wine density were a bit higher after short storing due to the water loosening during the storage. Measurements of red wine density were repeated after one week of storing and also after two weeks of storing (Fig. 2). Density values were also higher after storing so same proportion of curves were obtained after one week and after two weeks of storing as for white wine. Dependencies of whisky densities on temperature are presented on Figs. 3 – 4. For both types of whisky were obtained similar results. Densities were a bit higher after one week of storing and little higher after two weeks of storing. Next analysed sample was alcohol drink pinacolada. Density measurements were performed at the beginning of storage and also after one week of storing (Fig. 5). It can be seen that density values were higher after storing.

Table 1: Coefficients A and B of regression equation (2) and coefficients of determination R^2

Sample	**Regression equation (2)**					
	Coefficients					
	A [kg·m^{-3}]	**B[kg·m^{-3}]**	**R^2**	**A[kg·m^{-3}]**	**B [kg·m^{-3}]**	**R^2**
Pinacolada	First measurement			Next measurement		
	1 106.86	0.469 087	0.983 177	1 108.21	0.460 286	0.990 478
White wine	First measurement			Next measurement		
	995.566	0.239 273	0.981 496	995.815	0.240 978	0.995 244
Red wine	First measurement			Second measurement		
	996.724	0.233 637	0.959 312	996.998	0.233 877	0.958 711
	Next measurement			997.248	0.236 864	0.969 206
Whisky Grant´s	First measurement			Second measurement		
	962.187	0.588 991	0.984 428	962.539	0.586 741	0.986 502
	Next measurement			962.897	0.579 167	0.987 977
Whisky Jim Beam	First measurement			Second measurement		
	962.305	0.578 705	0.981 369	962.960	0.569 368	0.981 292
	Next measurement			963.251	0.562 989	0.978 113
Milk/Fat content	**A [kg·m^{-3}]**		**B [kg·m^{-3}]**		**R^2**	
0.5 %	1 036.55		0.276 969		0.991 812	
1.5 %	1 037.09		0.248 183		0.983 792	
3.5 %	1 036.00		0.286 364		0.988 326	

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

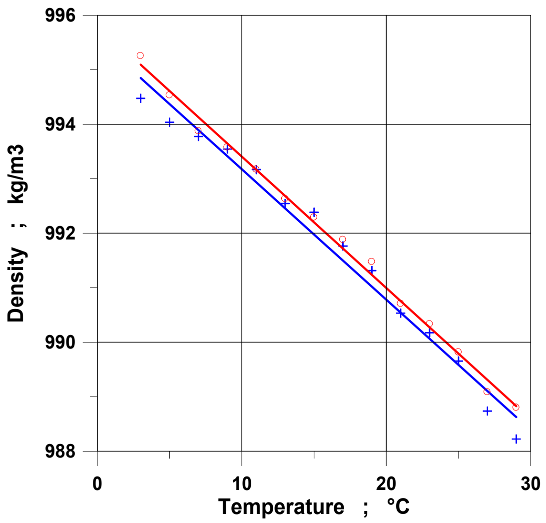

Figure 1
Temperature dependencies of white wine density
first measurement (+), next measurement (○)

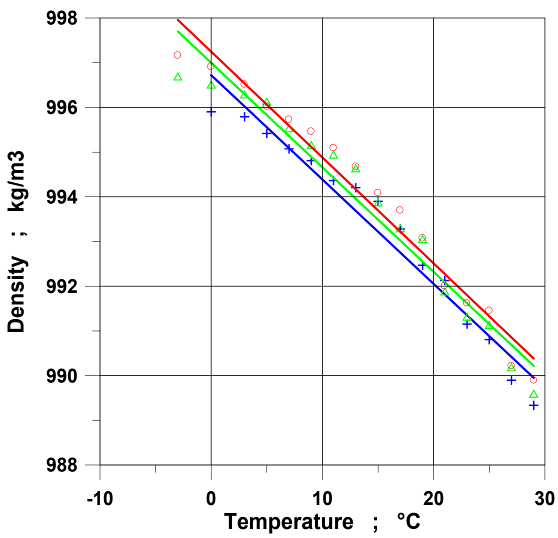

Figure 2
Temperature dependencies of red wine density
first measurement (+), second measurement (△), next measurement (○)

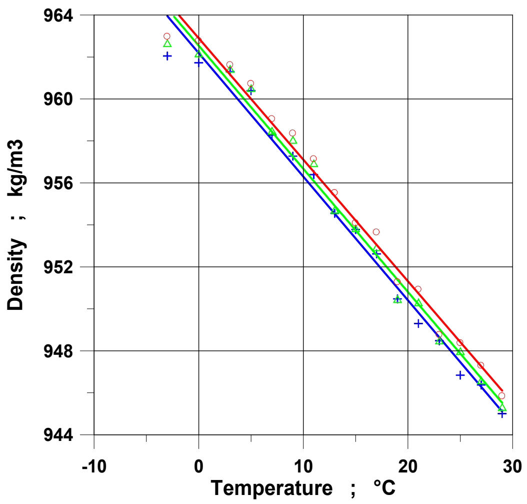

Figure 3
Temperature dependencies of whisky (Grant´s) density
first measurement (+), second measurement (△), next measurement (○)

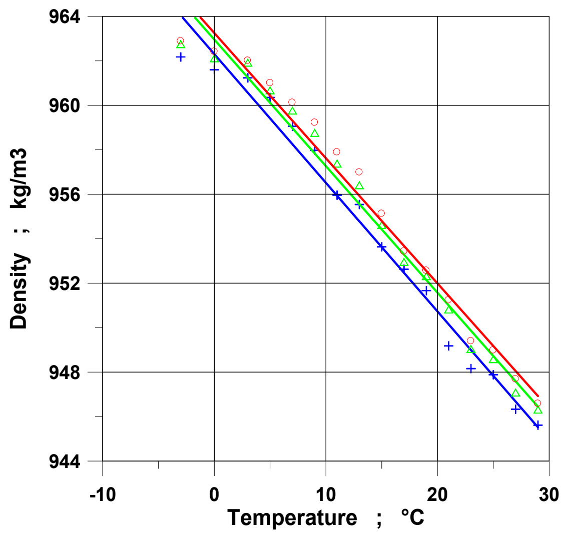

Figure 4
Temperature dependencies of whisky (Jim Beam) density
first measurement (+), second measurement (△), next measurement (○)

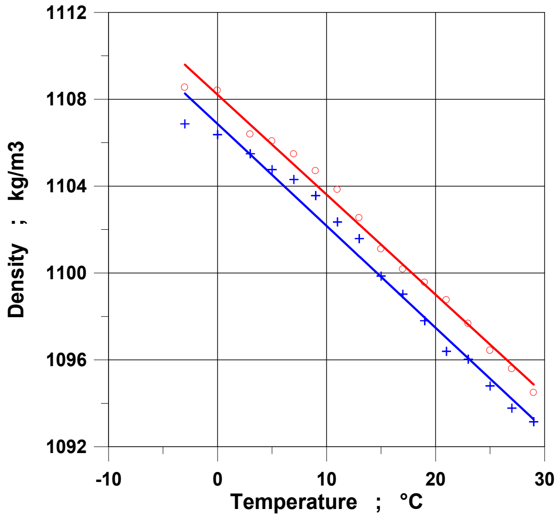

Figure 5
Temperature dependencies of pinacolada density
first measurement (+), next measurement (○)

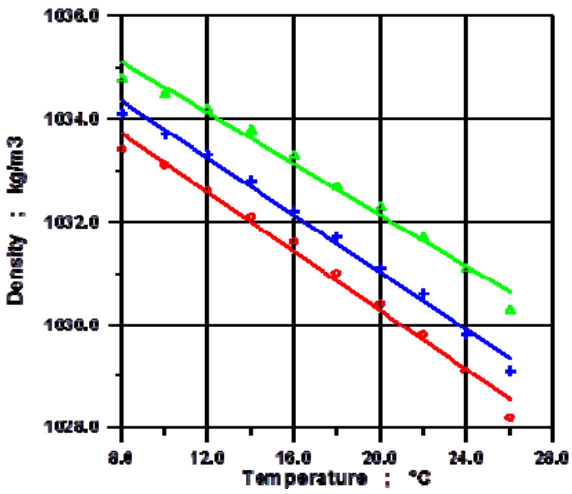

Figure 6
Temperature dependencies of milk density with fat contents
(+) 0.5 %; (Δ) 1.5 %; (○) 3.5 %

Effect of alcohol content on density had to be investigated together with material composition (wine, whisky, pinacolada). Wine with approximately 10 % of alcohol content had higher densities than whisky samples with 40 % of alcohol content. But on the contrary densities of pinacolada with 16 % of alcohol content were higher than other alcohol drinks, which is caused by its composition. Changes in density could be also caused by evaporation of alcohol during the heating and storing. On Fig. 6 are presented dependencies of density on temperature for milks with different fat content. The highest fat content of milk had caused the lowest density, but lower fat contents (less than 1.5 %) does not proved this proportion, this could be due to the different amount of proteins in measured samples of milk. Similar values and decreasing progresses of milk density with increasing temperature were observed by other authors (Kumbár and Nedomová, 2015; Alcantara, 2012; Dinkov et al., 2008; Oguntunde and Akintoye, 1991).

CONCLUSIONS

Effect of various factors on liquid food materials density was investigated in this article. Influence 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, pinacolada and three types of milk with different fat content. All measurements were performed in approximate temperature range (0 – 30) °C. Temperature dependencies of all measured samples densities are characterized by decreasing linear function in this temperature range, which is in accordance with other authors (Kumbár and Nedomová, 2015; Alcantara, 2012, Dinkov et al., 2008, Figura and Teixeira, 2007, Sahin and Sumnu, 2006, Oguntunde and Akintoye, 1991). The highest fat content of milk (3.5 %) had caused the lowest density, but lower fat contents (less than 1.5 %) does not proved this proportion, this could be due to the different amount of proteins in measured samples of milk. Effect of alcohol content on density had to be investigated together with material composition (wine, whisky, pinacolada). Lowest density of alcohol drinks had both types of whisky, and its alcohol content is highest (40 %). Wines with lower alcohol content (around 10 %) had higher densities. But on the contrary density of pinacolada with 16 % of alcohol content was higher than other alcohol drinks, which is caused by its composition. Alcohol content could be also changed due to evaporation during the heating and storage. Values of samples density were a bit higher after short storing due to the loosening of water during storage. Knowledge about physical properties and influencing factors of liquid food products can be used at determination of their quality.

ACKNOWLEDGEMENT

This work was supported by the project of VEGA 1/0854/14 of Ministry of Education, Science, Research, and Sport of the Slovakia and by Research Centre AgroBioTech built in accordance with the project Building Research Centre „AgroBioTech" ITMS 26220220180.

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