Biblid: 1821-4487 (2012) 16; 4; p 155-161
UDK: 582.711

Original Scientific Paper
Originalni naučni rad

RHEOLOGICAL BEHAVIOR OF QUINCE (*Cydonia oblonga*) PUREE

REOLOŠKO PONAŠANJE PIREA OD DUNJE (*Cydonia oblonga*)

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ABSTRACT

The objectives of the research presented in this paper are rheological properties of a mashed quince, variety Leskovac (Cydonia oblonga "Leskovačka"). The aim of this study was to investigate the influence of solids to the rheological properties of quince puree. For this purpose an experimental rheological testing of three samples of quince puree at room temperature of 20°C for different concentrations of dry matter: 8%, 10% and 12% was conducted with the rotational viscometer. It was found that the quince puree act as non-Newtonian, pseudoplastic fluid. The quince puree is thixotropic, with the apparent viscosity slightly variable with time. The change of apparent viscosity with time indicates that the quince puree hasn't got gel properties. Due to perceived yield stress, shear stress dependence on the shear rate (velocity gradient) is modeled with the Herschel - Bulkley model. The dependence of the apparent viscosity on the concentration of solids is modeled with exponential, power and logarithmic model, where it was found that the exponential model best represents the measured data, followed by the power and logarithmic model.

Key words: *rheology, puree, quince.*

REZIME

Predmet istraživanja u radu bio je pire napravljen od dunje sorte leskovačka (Cydonia oblonga „Leskovačka"). Cilj rada bio je da se ispita uticaj koncentracije suve materije na reološke osobine pirea od dunje. U radu je korišćena eksperimentalna metoda, gde je na rotacionom viskozimetru urađeno reološko ispitivanje tri uzorka pirea od dunje na sobnoj temperaturi od 20^{o}C i za različite koncentracije suve materije: 8%, 10% u 12%. Utvrđeno je da se pire od dunje ponaša kao nenjutnovski, pseudoplastični fluid. Priroda pirea je tiksotropna, gde se prividna viskoznost neznatno menja sa vremenom. Promena prividne viskoznosti sa vremenom ukazuje da pire od dunje nema osobine gela. Usled uočenog prednapona, zavisnost tangencijalnog napona od gradijenta brzine modelirana je Herschel – Bulkley modelom. Zavisnost prividne viskoznosti od koncentracije suve materije modelirana je eksponencijalnim, power i logaritamskim modelom, gde je ustanovljeno da eksponencijalni model najbolje reprezentuje izmerene vrednosti, zatim slede power i logaritamski model.

Ključne reči: *reologija, pire, dunja, leskovačka dunja.*

INTRODUCTION

There are only few papers on the rheological properties of the products of quince. *Bozkurt and Icier* (2009) investigated the rheological properties of quince nectar. They found that a nectar of quince at temperature range of 20°C to 75°C behaves as pseudoplastic, time-independent fluid. Samples were warmed up in two ways: by conventional heating and by ohmic heating. They have found that warming hasn't got any effect on the rheological properties of the nectar. Trigueros and others concluded that the quince, boiled in boiling water and added to yogurt, increases pH, reduces the amount of lactic acid and reduces the release of exopolysaccharides from lactic acid bacteria, which contributes to the reduction of the apparent viscosity of yogurt (*Trigueros et al., 2011*).

In 1970 Saravacos has experimentally determine the effect of temperature on viscosity of fruit juices and purees (*Saravacos, 1970*). In 1977, Rao found that the overall pulp and purees made from fruits and vegetables act as non-Newtonian, pseudoplastic fluids. Since then, it was worked intensively on studying the rheological properties of fruit purees. The viscosity of a fluid is affected by: shear rate (velocity gradient), temperature, pressure, humidity, and composition during storage (*Giap at all., 2010*). Hence, the studies were focused to determine the impact of listed properties to the rheological properties of fruit puree.

Ramos and Ibarz (1998) investigated the rheological properties of quince puree. They found that the quince puree is thixotropic under the following conditions: the concentration of soluble matter from 12.3 to 28 oBx, a temperature from 0 to 20°C and shear rate of 7.2 to 57.6 s-1. Thixotropic behavior of quince puree was more pronounced with increase of soluble solids concentration and temperature decrease. It was concluded that the quince puree has more pronounced thixotropic character compared to the juice from the oranges. The reason for this is the higher content of fiber, pulp and pectin and microscopic structure of quince puree consisting of long particles and heterogeneous fibers. In the same year was concluded (*Guerrero and Alzamora, 1998*) that the different content and proportion of pectin fractions in fruit purees of peach, mango and papaya may be the reason for the difference in the rheological properties behavior with changes in the concentration of dissolved substances. Also, the peach puree rheological properties were investigated (*Akdogap and McHugh, 1999*). It was found that the apparent viscosity of peach puree decreases with temperature and moisture increase.

The factors of influence to the rheological behavior of fluid food, among others, are: the total content of dry matter, particle size, total dissolved solids and temperature (*Ahmed et al., 2000*). The concentration of soluble and insoluble solids have strong non-linear effect on the viscosity of Newtonian fluid, consistency index and apparent viscosity of non-Newtonian fluid (*Krokida et al., 2001*). This assertion was confirmed later by Belestra who said that fruit purees is made of serum which is the usually Newtonian fluid with particles of different sizes and shapes scattered across it, and where pulp with pectin is a component that contributes to non-Newtonian behavior (*Balestra at al, 2011*). Complex interactions between soluble sugars, pectin substances and suspended solid particles significantly affect the rheological behavior of fruit purees (*Balestra et al., 2011*).

Sumahy investigated guava puree rheological bahavior (*Samahy et al., 2003*). When the guava puree, before being concentrated, is treated with pectinex Ultra SP-L enzyme a change in rheological behavior occures, and concentrated puree becomes Newtonian fluid. When the guava puree is treated with PL rohament enzyme, than the rheological behavior is not changed, and puree behaves as pseudoplastic, thixotropic fluid. Ahmed and Ramaswamy determined, by measuring and application of the response surface methodology, following sequence of influencing properties and their values to the rheological behavior of papaya puree: temperature (5 - 65°C), TSS (10 - 30°Brix), pH (3 - 7) and α - amulase concentration (0.25 - 1.25 kg/kg of dry matter) (*Ahmed and Ramaswamy, 2004*). Tabi-Munizaga investigated the rheological properties of avocado puree at a very high pressure of 517, 600 and 676 MPa and a temperature of 21°C (*Tabi - Munizaga et al., 2005*). They found that higher pressure affects the yield stress that increases with pressure increase.

Ditchfield and others found that the bananas puree is a time dependent over a wide range of temperatures (40, 50, 60, 80, 90, 100, 110, 120°C), except at 90°C (*Ditchfield at all., 2004*). At this temperature there is a structural change during measuring. There is a significant change in the rheological behavior of banana puree between 50oC and 60oC. Heating processes affect the amount of total dissolved solids in the puree, changing the viscosity of the product (*Dutta et al., 2006*). Maceiras and others (*Maceiras, at al, 2007*) showed that purees of selected fruits (raspberries, strawberries, peaches and plums) have non-Newtonian behavior and have a lower value of the apparent viscosity of fruit jam, where the apparent viscosity increases with puree cooking. The method of preparation and storage duration affects the viscosity of puree and it was confirmed on strawberry puree (*Osorio at al., 2009*). The rheological behavior of four samples of strawberry puree was analyzed: fresh puree, lightly pasteurized (75°C - 15 s), very pasteurized (90°C - 20 s) and hot-filled purees (90°C - 2 min). The viscosity increase of hot-filled purees compared to the viscosity of fresh strawberry puree was observed, which is explained by the change in fractions of pectin caused by high temperatures. Rheological properties recording was done at intervals of 0, 30 and 60 days, where it was noted that the storage duration has an impact on the rheological properties of strawberry puree. During storage, consistency index decreases, while the index of flow behavior increases.

It was found that the adding glucose has no effect on the change of yield stress and consistency index of pumpkin puree, while addition of xylitol reduces yield stress and consistency index during storage (*Gliemmo et al., 2009*). It was found (*Falguera et al., 2012*) that the factor that has the greatest impact on the index of peach puree consistency is the date when the peaches were harvested, and the concentration of solids is next.

The object of research presented in this paper is puree from mashed quince, varieties Leskovac (Cynodia oblonga "Leskovačka"). The aim of the study was to investigate the effect of solids concentration on the rheological properties of quince puree. In the research was used the experimental method, where rheological testing was done on three samples of quince puree of different concentrations of dry matter: 8%, 10% and 12%. Rao has implied the pseudoplastic nature of fruit purees (*Rao, 1977*). Up to now conducted rheological tests of fruit purees, including Krokida's (*Krokida et al., 2001*) ten different researched fruit purees, confirmed the pseudoplastic nature of fruit purees. It is assumed that the quince puree acts as non-Newtonian, pseudoplastic, thixotropic fluid, where the concentration of solid matter of quince puree significantly effects on the change of apparent viscosity.

Nomenclature

A - constant
B - constant
$C(\%)$ - dry matter concentration
$K(\mathrm{Pa}\cdot\mathrm{s}^n)$- consistence index
$n(-)$ - flow behavior index
$n(\mathrm{rmp})$ - number of rotation
$R_c(\mathrm{m})$ - radius of container
$R_b(\mathrm{m})$ - radius of spidle
$t(\mathrm{s})$ - time
$x(\mathrm{m})$ - radius at which shear rate is being calculated

Greek symbols
$\dot{\gamma}(s^{-1})$- shear rate
$\eta(\mathrm{Pa}\cdot\mathrm{s})$- viscosity
$\tau(\mathrm{Pa})$- shear stress
$\tau_0(\mathrm{Pa})$- yield stress
$\omega(\mathrm{rad/s})$ - angular velocity of spidle

Subscripts
pre – predicted
mer – measured
1 – exponential model
2 – power model
3 – logarithmic model

MATERIAL AND METHOD

Quince "Leskovačka" is the highest quality quince variety in our region. It ripens in October and provides globular fruit, lemon yellow, weighing about 250 g. It is recognizable by the fruit stem bulges, pungent and strong odor. The flesh is firm, juicy and tastes sweet and sour. It withstands several months of storage.

Quince puree was prepared as follows: quince was washed, stems removed and quince was peeled, sliced, the seeds were removed from the interior of quince, quince slices were cooked in water and then mashed to obtain the puree. The quince "Leskovačka" puree was preserved with sodium - benzoate for the purpose of storage and further investigation of the rheological properties.

The basic sample with 12% dry matter concentration was diluted with distilled water, and two other samples were obtained, with 10% and 8% concentration of dry matter. The concentrations of dry matter of the samples, 700 ml of volume, were determined with the moisture analyzer "Kern and Sohn" model MLB50-3N. The measuring range of the device is up to 50 g, with 0.001 g resolution / 0.01%, repeatability (sample weight 2 g) and 0.5% (10 g sample weight) 0.02%. Three measurements of part of the dry matter were performed for the sample, where the concentration of dry matter in the sample was determined as the arithmetic mean.

In order to determine the impact of solid matters to the rheological behavior of quince puree the viscometer manufactured by "Myr", model "V2-R" (Brookfield viscometer) was used. The accuracy of the viscometer is 0.5% of the measured value; the measuring range is 20 ÷ 13 million mPas, while the accuracy of measurement is ± 1% for the entire measuring range. The sample was heated in a water bath, and the temperature was controller using PT 100 temperature probe of the viscometer. Measuring range of the temperature probe is -15 ÷ 180˚C, resolution 0.1˚C, accuracy ± 0.1˚C, while the accuracy is ± 1% for the entire measuring range.

Rheological curves were measured for the samples of quince puree of different concentrations of dry matter: 8%, 10% and 12%. For each sample, at a given concentration of solid matter, were recorded two rheological curves, one by increasing of a shear rate and the other by decreasing shear rate. Rheological curve was obtained as the arithmetic average of the two measured rheological curves. The range of cylinder spindle was from 0.3 to 200 rpm. In order to determine the time dependence, the rheological characteristics of quince puree with concentration of dry matter of 12% were measured at room temperature of 20˚C for 5 h. The measurements were performed at the following shear rates: 0.65 s^{-1}, 1.31 s^{-1}, 10.93 s^{-1} and 21.87 s^{-1}. Rotational viscometer manufactured by "Myr" model "V2-R" was controlled by computer and software package for the viscometer Viscosoft Plus V2 version v1.05 which was used for data processing.

According to the recommendations for the viscometer type "Brookfield" (Brookfield Engineering) based on measured rpm of cylinder, shear rate $\dot{\gamma}$ was determined as:

$$\dot{\gamma} = \frac{2 \cdot R_c^2 R_b^2}{x^2\left(R_c^2 - R_b^2\right)}\omega, \qquad (1)$$

where the angular velocity is:

$$\omega = \frac{2\pi n}{60}. \qquad (2)$$

Shear stress is defined as the product of the measured apparent viscosity and shear stress:

$$\tau = \eta \cdot \dot{\gamma}, \qquad (3)$$

where the rheological behavior of quince puree was modeled with the Herschel-Bulkley model:

$$\tau = \tau_0 + K\dot{\gamma}^n. \qquad (4)$$

The dependence of the apparent viscosity and the dry matter concentration of quince puree is modeled using three models: exponential law, power law and logarithm law:

$$\eta = A_1 \cdot \exp\left(B_1 \cdot C\right), \qquad (5)$$

$$\eta = A_2 C^{B_2}, \qquad (6)$$

$$\eta = A_3 \ln\left(C\right) + B_3. \qquad (7)$$

RESULTS AND DISCUSSION

The dependence of the apparent viscosity on the velocity gradient of quince puree at a temperature of 20°C and dry matter concentration of 8%, 10% and 12% is shown in Figures 1, 2 and 3. The curves were recorded by increasing and decreasing cylinder rpm. It can be noticed that there is a small hysteresis in each figure, recorded between curves gained for increasing and decreasing cylinder rpm. Curve taken at higher speeds has a higher value of the apparent viscosity than the curve recorded by reducing cylinder rpm. This hysteresis explains thixotropic nature of quince puree, where the apparent viscosity of puree decreases over time. The explanation is in line with the tendency of fruit purees to have tixotropic nature, as confirmed in many studies of: quince puree *(Ramos and Ibarz, 1998)*, guava puree *(Samahy et al., 2003)*, mashed avocado *(Tabi - Munizaga et al., 2005)*, mashed bananas *(Gliemmo et al., 2009)*, peach puree *(Masa et al., 2010)* etc.

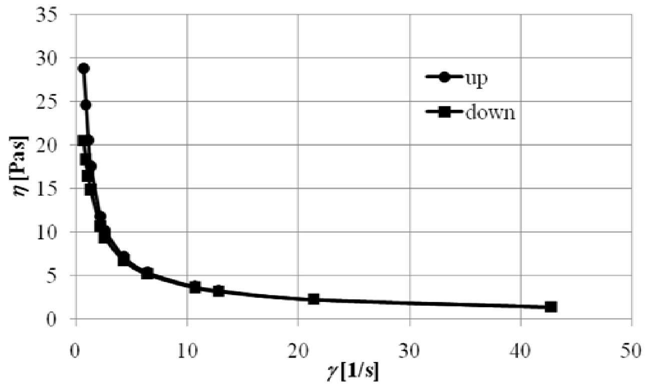

Fig. 1. The apparent viscosity of quince puree at a temperature of 20°C and with dry matter concentration of 8%

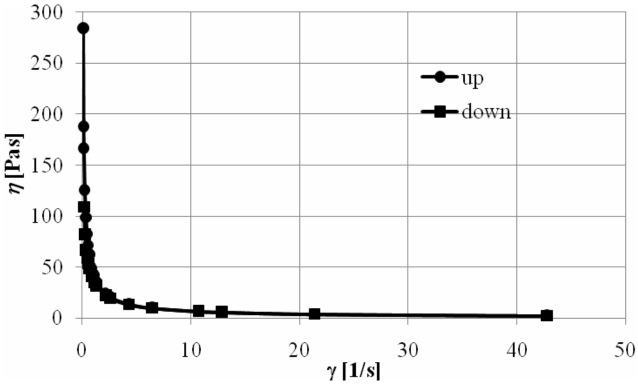

Fig. 2. The apparent viscosity of quince puree at a temperature of 20°C and with dry matter concentration of 10%

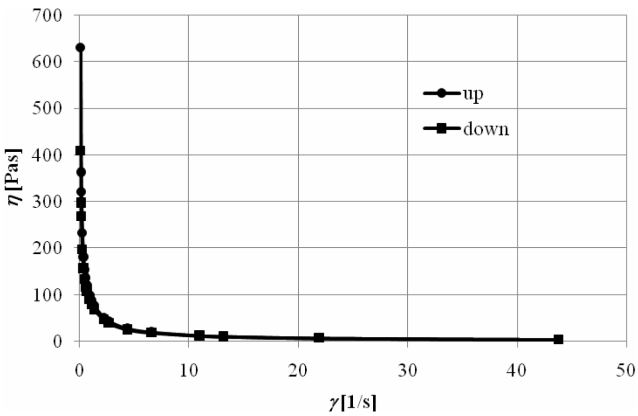

Fig. 3. The apparent viscosity of quince puree at a temperature of 20°C and with dry matter concentration of 12%

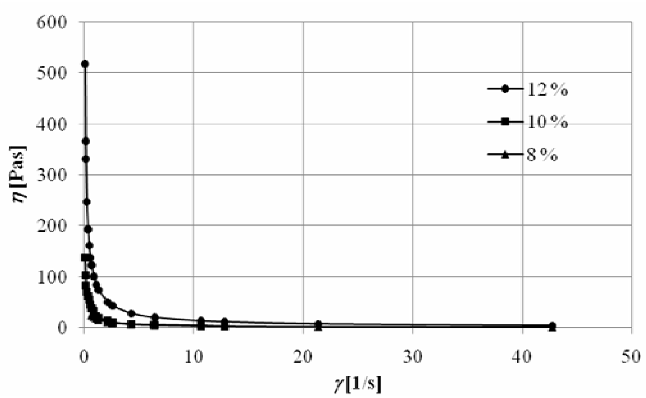

Fig. 4. The apparent viscosity of quince purees at a temperature of 20°C and with dry matter concentrations of 8%, 10 % and 12%

Due to the observed hysteresis arising from changes in viscosity over time, it is recommended that the rheological curves are recorded by increasing and decreasing cylinder rpm. The final rheological curve is than obtained as the arithmetic average of the two recorded curves *(Falguera at al, 2012)*. Figure 4 shows the dependence of the apparent viscosity, shear rate and concentration of dry matter of quince puree at a temperature of 20°C, where the curves are obtained by averaging measured curves. The dependence indicates that the quince puree at a temperature of 20°C and dry matter concentration of 8%, 10% and 12% acts as non-Newtonian, pseudoplastic fluid, where the apparent viscosity decreases with increasing shear rate. Pseudoplastic fluid behavior is explained by the cracking of the molecule structure when exposed to hydrodynamic forces and by increasing the alignment of the constituent molecules *(Balestra at al., 2011)*.

With the aim to confirm the thixotropic nature of quince puree the log - linear dependence of the apparent viscosity, time and shear rate of puree at a temperature of 20°C and dry matter concentration of 12% was drawn, Figure 5. Very small hysteresis between the curves, obtained by increasing and decreasing rpm of cylinder is shown in Figures 1, 2 and 3. It indicates that the time change of apparent viscosity is very small, almost negligible. The only noticeable drop in apparent viscosity over time corresponds to a shear rate of 21.87 s^{-1}. In the log - linear graph of the apparent viscosity over time can be estimated that the quince puree has the properties of gel (Brookfield Engineering). Since curves have a very small slope, and decrease in the apparent viscosity is gradual, it can be concluded that the quince puree at the given conditions does not have gel properties.

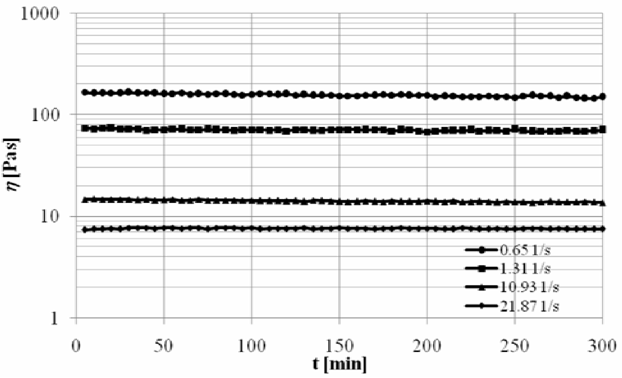

Fig. 5. The thixotropic nature of quince puree at a temperature of 20°C, the concentration of dry matter of 12% and shear rates of 0.65 s^{-1}, 1.31 s^{-1}, 10.93s^{-1} and 21.87 s^{-1}

Due to the presence of yield stress in fruit puree, modeling of rheology behavior is mainly successfully done using the Herschel - Bulkley model: peach puree, mango and papaya *(Guerrero and Alzamora, 1998)*, banana puree *(Ditchfield et al., 2004)*, papaya puree *(Ahmed and Ramaswamy, 2004)*, avocado puree *(Tabilo - Munizaga et al., 2005)*, pumpkin puree *(Dutta et al., 2006)*, *(Gliemmo et al., 2009)* etc. It is interesting that despite the fact that purees generally have a yield stress (*Maceiras et al., 2007*) it is possible to successfully model the rheological behavior of puree of raspberries, strawberries, peaches and plums with the Ostwald de Waele model. Also, the Ostwald de Weale model was successfully applied for the rheological behavior of fruit dragon puree *(Liaotrakoon et al., 2011)*. It should be mentioned the work of Nindo (*Nindo et al., 2007*), who successfully (R^2 = 0.99) model the rheological properties of blueberries puree with the Sisko model, which is a combination of the Newtonian and the Ostwald de Waele model.

Equations (1), (2) and (3) established the dependence of shear stress and shear rate of quince puree at a temperature of 20 °C and dry matter concentration of 8%, 10% and 12%. The dependence is presented in Figure 6, which clearly shows that the viscosity of quince puree was measured at very low values of shear rates. The minimum value of the shear rate was 0.064 s^{-1}, which corresponded to 0.3 rpm of cylinder. At such low values of recorded shear rate, a rheological curve is obtained, which can easily be extrapolated to estimate the yield stress τ_0 quince puree. The extrapolation of rheological curves showed that the quince puree has a yield stress given in Table 1. For the purpose of modeling of the rheological behavior of quince puree, due to yield stress, was used the Herschel-Bulkley model, equation (4), which includes a yield stress.

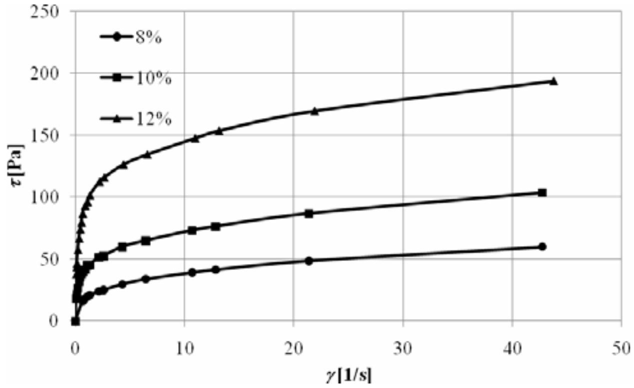

Fig. 6. The rheological curves of quince puree with dry matter concentrations of 8%, 10% and 12% and temperature of 20°C

Table 1 shows the dependence of parameters of the Herschel-Bulkley model on dry matter concentration of quince puree at a temperature of 20°C. The Herschel-Bulkley model fits well the measured values which can be seen from the values of coefficient of determination R^2. For the puree with dry matter concentration of 8% and temperature of 20°C coefficient of determination R^2 is very high (=0.998). It is evident that with decreasing puree dry matter concentration, the Herschel-Bulkley model better represents the experimental data. As the dry matter concentration in the quince puree increases, the values of the consistency coefficient *K* and yield stress also increase, while the value of the index of flow behavior *n* decreases. This trend of the consistency index and the index of flow behavior changes, albeit for the soluble part of dry matter was confirmed for purees: mango and papaya *(Guerrero and Alzamora, 1998)*, commercial, fruit, baby purees *(Alvarez et al., 2008)* and peach *(Mass et al., 2010)*.

Table 1. The dependence of the Herschel - Bulkley model parameters on dry matter concentration of quince puree at a temperature of 20°C

$C(\%)$	$\tau_0\,(\mathrm{Pa})$	$K\,(\mathrm{Pa\cdot s^n})$	$n\,(-)$	R^2 (-)
8	0.15	18.96	0.307	0.998
10	0.45	40.80	0.262	0.981
12	2.1	86.05	0.246	0.964

The dependence of the apparent viscosity on the dry matter concentration of quince puree is modeled using three models: the exponential law (5), the power law (6) and the logarithm law (7). Since at constant temperature and concentration of dry matter apparent viscosity of fruit products depends on the shear rate (*Shamsudin at al, 2008*), the parameters of equation (5), (6) and (7) are modeled for different values of the shear rates. In Tables 2, 3 and 4 are shown the dependences of the parameters of the exponential, power law and logarithmic model on the shear rate for quince puree at a temperature of 20°C.

Table 2. The dependence of the parameters of the exponential model on the shear rate of quince puree at a temperature of 20°C

$\dot{\gamma}\left(s^{-1}\right)$	A_1	B_1	R^2 (-)
0.641	1.244	0.375	0.998
0.854	1.165	0.364	1
1.068	0.968	0.368	1
1.282	0.851	0.368	0.999
2.136	0.63	0.36	1
2.564	0.582	0.352	1
4.273	0.500	0.329	0.999
6.410	0.408	0.32	0.999
10.68	0.332	0.3	0.999
12.82	0.311	0.293	0.999
21.36	0.245	0.279	0.999
42.73	0.174	0.261	0.999

Table 3. The dependence of the parameters of the power law model for the shear rate of quince puree at a temperature of 20°C

$\dot{\gamma}\left(s^{-1}\right)$	A_2	B_2	R^2 (-)
0.641	0.011	3.702	0.999
0.854	0.012	3.587	0.997
1.068	0.009	3.624	0.996
1.282	0.008	3.616	0.995
2.136	0.007	3.541	0.996
2.564	0.007	3.467	0.996
4.273	0.008	3.244	0.998
6.410	0.007	3.147	0.997
10.68	0.007	2.960	0.998
12.82	0.007	2.893	0.999
21.36	0.007	2.753	0.999
42.73	0.006	2.573	0.999

Based on the value of coefficient of determination R^2 it can be estimated which of the proposed models best represents the measured data. The highest value of the coefficient of determination R^2 has the exponential model, Table 2, where the value of R^2 is independent of the high-shear rates and is 0.999. Slightly lower, but still very high value of coefficient of determination R^2 has a power law model, Table 3, while the lowest value of the coefficient of determination R^2 has a logarithmic model, Table 4.

It is interesting that there is no law of change of coefficient of determination R^2 with changing shear rate, which could be expected because at higher values of the shear rates measurement of viscosity are more accurate. At lower values of shear rates, a big fluctuation of measured viscosity appears (*Giap, 2010*). For all of the recorded values of shear rates (include the whole range of measuring rotational viscometer) the apparent viscosity changes can be very accurately described with the exponential and power law model.

As all three models have R2 greater than 0.9. The verification of the mathematical model was done in a way that the measured values and the values determined by the mathematical model were compared. Figures 6, 7, 8 and 9 show the comparison of measured and predicted values of the apparent viscosity of quince puree at a temperature of 20°C, for the following shear rates: 0.64 s^{-1}, 2.62 s^{-1}, 12.5 s^{-1} and 42.73 s-^{1} .

Table 4. The dependence of the logarithmic model parameters for the quince puree at a temperature 20°C

$\dot{\gamma}\left(s^{-1}\right)$	A_3	B_3	R^2 (-)
0.641	209.6	-416.3	0.951
0.854	172.5	-342	0.937
1.068	151.51	-300.8	0.932
1.282	132.2	-262.6	0.931
2.136	87.94	-174	0.936
2.564	73.651	-145.3	0.939
4.273	46.28	-90.39	0.952
6.410	33.3	-64.79	0.949
10.68	20.82	-40.08	0.957
12.82	17.67	-33.87	0.962
21.36	11.43	-21.72	0.966
42.73	6.30	-11.82	0.969

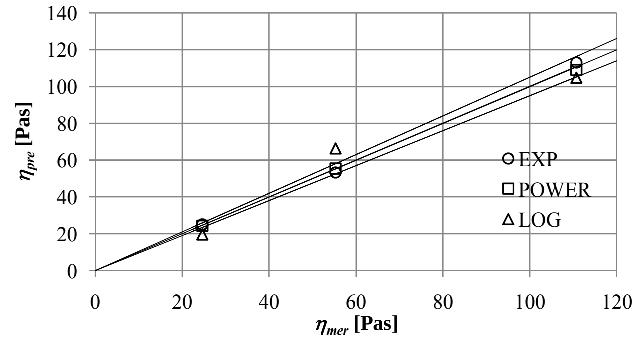

Fig. 6. Quince puree at a temperature of 20°C and the shear rate of 0.641 s^{-1}

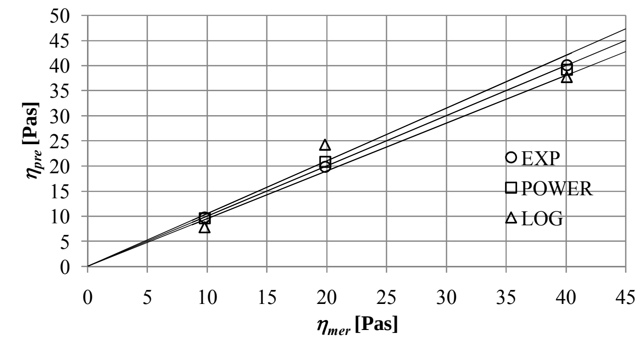

Fig. 7. Quince puree at a temperature of 20°C and the shear rate of 2.62 s^{-1}

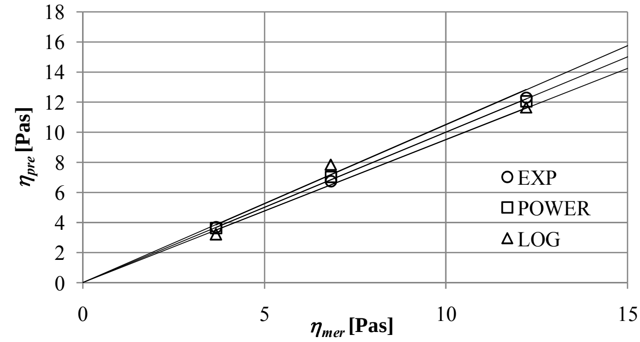

Fig. 8. Quince puree at a temperature of 20°C and the shear rate of 12.50 s^{-1}

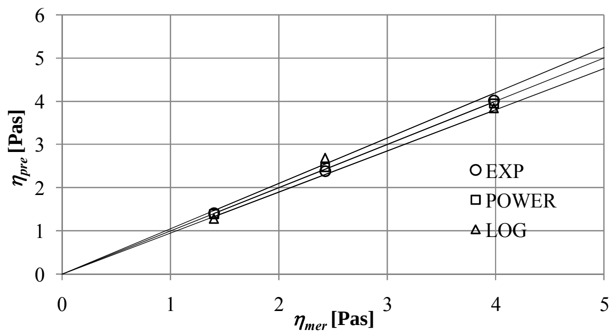

Fig. 9. Quince puree at a temperature of 20°C, and the shear rate of 42.73 s^{-1}

Comparing the measured values of the apparent viscosity and values predicted by mathematical model, it is confirmed that the exponential model best represents the measured values of the apparent viscosity, followed by the power model and the logarithmic model. It can be observed that the difference between the measured and predicted values of apparent viscosity in exponential and power models are always in the range of +/- 5%, while in the logarithmic model it always goes outside this range. In this way it is shown that the logarithmic model, despite the relatively high values of R^2 (for a given range of shear rates shown in Table 4 range from 0.931 to 0.969) is not an adequate model to describe the dependence of the apparent viscosity of the dry matter concentration of quince puree.

CONCLUSION

This paper deals with puree of quince "Leskovac" and its rheological behavior. The influence of dry matter concentration on the rheological properties of quince puree was investigated. The experimental method was applied, where rheological testing was done on three samples of quince puree of different concentrations of dry matter: 8%, 10% and 12%.

It is found that the quince puree acts as non-Newtonian, pseudoplastic fluid, where the apparent viscosity η decreases with the shear rate increase. Quince puree has a thixotropic nature, where the apparent viscosity change in time is relatively small. Analysis of the log - linear graph of the apparent viscosity vs. time showed that quince puree has not gel properties. It was observed that the quince puree has a yield stress τ_0. For this reason, the dependence of shear stress τ and shear rate was modeled with the Herschel - Bulkley model. The Herschel - Bulkley model represents well the measured data. R^2 increases with puree dry matter concentration decrease, and for the dry matter concentration of 8% it reaches 0.99. Parameters of the Herschel - Bulkley model show that as the dry matter concentration in quince puree increases, there is an increase of consistency coefficient K and yield stress τ_0, and decrease of flow behavior index n.

The dependence of the apparent viscosity and dry matter concentration of quince puree at room temperature of 20°C was modeled with the exponential, logarithmic and power model. The modeling was done for different values of the shear rates. According to the value of coefficient of determination R^2 it is concluded that the exponential model best represents the measured data (R^2 = 0.99), followed by power model (R^2 = 0.99) and at the end, the logarithmic model (R^2 = 0.931-0.969). This trend of the adequacy of mathematical models is confirmed also with comparison of the measured values of the apparent viscosity and predicted values analyzed by mathematical models. It was found that the difference between the measured values and the predicted values for the exponential and power models are always within +/- 5%, while for the logarithmic model they are always outside the +/- 5%. In this way, it can be concluded that despite the relatively high value of coefficient of determination R^2 of the logarithmic model, it is not adequate for modeling the dependence of the apparent viscosity of the dry matter concentration of quince puree.

ACKNOWLEDGMENT: This paper is the result of the project titled: "Integrated and organic fruit and vegetable products drying by combined technology" (Project No. TR31058) funded by the Ministry of Education and Science of the Republic of Serbia.

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Received:08.02.2103. Accepted:01.04.2013.