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# Determination of rheological properties of some pekmez samples in Turkey

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**Abstract**

The rheological behaviors of pekmez samples (mulberry, grape, rosehip and harnup juice) were investigated. Viscosity was measured at 5, 10, 15, 20 and 30 °C using a rotational viscometer in the shear rate range of 0–93 $s^{-1}$. An emprical power-law model was used to describe the rheological behaviors of pekmez samples. Pekmez samples were found to exhibit non-Newtonian behaviors. An Arrhenius equation was used to determine the effect of temperature on viscosities of pekmez samples and thus $E_a$ values of pekmez samples were calculated. The activation energies vary from 18.509 to 74.658 kJ/mol depending on the solid contents (39.44, 60.48, 67.08, 69.68, 71.98, 74.22, 75.4 and 75.46 °Brix).


*Keywords:* Pekmez; Viscosity; Power-law model; Arrhenius equation

## 1. Introduction

A number of foods are fluids. In the food industry, characterization of flow behavior is important not only in operations involving the processing and transportation of food, but also in terms of defining a set of parameters used as quality indexes that can be objectively determined (Toledo, 1980). Pekmez is the one of the most common and known mulberry and grape products in Turkey. Pekmez is a concentrated and shelf-life extended form of mulberry or grape juice formed by boiling without the additional of sugar or other food additives (Gökçen, Ömeroğlu, & Ceritoğlu, 1982; Tekeli, 1965; Yazıcıoğlu, 1967). For this reason it can be assumed as a natural food containing natural sugars such as glucose, galactose and minerals. Since pekmez contains high amounts of sugar, mineral and organic acid, it is a very important food product in human nutrition (Demirözü, Sökmen, Uçak, Yılmaz, & Gülderen, 2002; Üstün & Tosun, 1997).

Pekmez processing operations vary according to origin of fruits used in production of pekmez. Fresh mulberry is used as a raw material to produce mulberry pekmez. First, mulberry is placed to boiling vessels after washing and then water of 8–10 l is added for mulberry of 20–30 kg. After addition of water, the mixture is boiled and stirred completely for about one hour. After then, the mixture is cooled up to about 40–50 °C. In order to obtain clear mulberry juice, the cold mixture is pressed and then filtered. Mulberry juice is concentrated by vaporing water in open vessels to obtain a final product having 65–72 °Brix. Final product, called mulberry pekmez, is packaged and stored at room temperature (Aksu & Nas, 1996).

In the food industry, rheological characteristics of concentrated fruit juices are significant properties in addition to chemical and physical properties. Moreover, rheological characteristics depend on both the chemical compositions of fruits and processing conditions (Şengül, Ertugay, & Şengül, 2005). However, the knowledge of the flow behaviors of concentrated fruit juices will be useful in quality control, calculating energy usage, process control and equipment selection (Kaya & Belibağlı, 2002). In order to

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use new technologies such as modern evaporation systems, knowledge of the flow properties of liquid pekmez is important for determining the process parameters the type of evaporator, direction of feed and heat transfer rate are all effected by the viscosity of fruit paste (Crandall, Chen, & Carter, 1982). Viscosity, a rheological property, is also considered as an important physical characteristic related to the quality of liquid food products (Saravacos, 1970).

There are a number of researches about rheological properties of grape pekmez (Alpaslan & Hayta, 2002; Kaya & Belibağlı, 2002; Şengül et al., 2005). However, there is little information about rheological properties of mulberry, rosehip and harnup pekmez. Therefore, the goal of this work is to determine rheological behaviors of mulberry, grape, rosehip and harnup pekmez as a function of temperature.

## 2. Materials and methods

Eight pekmez samples were selected in this study. Letters A and B written with the fruit names denote type of the pekmez not that of the fruit. The origins of these pekmez samples were white mulberry (A, B), black mulberry, white grape (A, B), black grape, rosehip, and harnup fruits. While the pekmez samples obtained from black mulberry and harnup fruits have been produced from a factory, the rest of pekmez samples have been produced by traditional producing methods.

### 2.1. Preperation of pekmez samples

Viscosity of pekmez can be influenced by the presence of crystals and air bubbles. To ensure complete removal of crystal nuclei and air bubbles, all the pekmez samples were, therefore, heated up to 60 °C for 48 h in water bath. To minimize the chances of recrystallisation, the very same samples were then stored at 5 °C until analysis.

### 2.2. Total soluble solid content

Total soluble solid contents of pekmez samples (°Brix) were measured at 20 °C using digital refractometer (METTLER TOLEDO RE50, Switzerland).

### 2.3. Rheological characterisation of pekmez samples

Viscosity measurements of pekmez samples were made using a Brookfield DV II+ model viscometer with temperature controller unit (HT-110) and thermosel system (HT-60DP). The viscosity measurements were carried out at different shear rates (0–93 $s^{-1}$) and temperatures ranging from 5 °C to 30 °C.

As stated previously, in this analysis the pekmez samples are described by power-law model in which viscosity is defined as follow.

$$\eta = k\dot{\gamma}^{n-1} \quad (1)$$

where $\dot{\gamma}$ is shear rate, $k$ is consistency coefficient and $n$ is the flow behavior index. For $n < 1$, the model is pseudoplastic (shear thinning); $n > 1$, the model is dilatant (shear thickening). The consistency index, $k$, apparent viscosity, $\eta$, and power-law index, $n$, can be determined by ploting $\ln(\eta)$ versus $\ln(\dot{\gamma})$. Linear regression analysis was performed to find $k$, $n$ and correlation coefficient $r^2$.

Effect of temperature on the apparent viscosity of pekmez samples at a specified shear rate was determined by using the Arrhenius model (Rao, Cooley, & Vizali, 1984; Saravacos, 1970).

$$\eta = \eta_0 \exp(E_a/RT) \quad (2)$$

where $\eta_0$ is a constant, $E_a$ the activation energy for flow, $T$ the absolute temperature and $R$ the universal gas constant. A linear plot of $\ln(\eta)$ versus $(1/T)$ was drawn to obtain the activation energy. The mean absolute percentage error ($MA\%E$) was calculated to analyze the deviance of observed value from the calculated value (Mayer & Butle, 1993).

$$MA\%E = \frac{100}{n}\sum\left[\frac{|Y_o - Y_c|}{Y_c}\right] \quad (3)$$

where $Y_o$ represent observed values, $Y_c$ the calculated values and $n$ the number of pairs.

## 3. Result and discussion

### 3.1. Total soluble solid contents

The each pekmez sample used in this study contains a certain amount of soluble solid material that is given in Table 1 in terms of °Brix. As can be seen in Table 1 while the largest content of solid material belongs to black grape specimen (75.46 °Brix), the lowest that of solid material belongs to rosehip specimen (39.44 °Brix). The soluble solid material contents of the rest of samples vary in the range of this interval (75.46–39.44 °Brix). As can be seen Table 1 the pekmez samples contain the soluble solid materials in a wide range of the interval.

### 3.2. Rheological characterisation of pekmez samples

#### 3.2.1. Power-law model

The viscosity of white mulberry pekmez as a function of shear strain was graphically shown in Fig. 1. As can be seen

Table 1
Total soluble solid contents of pekmez samples

| Pekmez samples | Total soluble solid (°Brix) |
|---|---|
| White Mulberry A | 75.40 |
| White Mulberry B | 60.48 |
| White Grape A | 74.22 |
| White Grape B | 71.98 |
| Black Mulberry | 67.08 |
| Black Grape | 75.46 |
| Rosehip | 39.44 |
| Harnup | 69.68 |