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RHEOLOGICAL CHARACTERISTICS OF TRADITIONAL SALEP DRINK FLAVORED WITH COCOA POWDER

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Abstract
In this study, the rheological characteristics of salep drink flavored with cocoa powder were determined. Salep drink was prepared with the incorporation of different cocoa powder concentrations (1, 2 and 3%) into the mixture of milk, sugar and salep powder. The apparent viscosity of samples was measured at different temperatures (10, 20 and 30 oC) with a controlled stress/strain rheometer. The consistency coefficient and flow behavior index of salep drinks were calculated by utilizing the empirical power law model. All samples showed a non-Newtonian pseudoplastic behavior and apparent viscosity decreased with increasing shear rate. Also, at all temperatures, apparent viscosity of samples increased with increasing amount of cocoa powder and decreased with an increase in temperature for all cocoa concentrations in salep drink. The flow behavior index of samples was in the range of 0.231-0.326 while the consistency coefficient changed in the range of 7.365-21.277 Pa.sn. The Arrhenius equation was used to describe the temperature dependence of viscosity and the activation energy was calculated as in the range of 3.26 to 17.38 kJ/mole.

Keywords: salep, cocoa powder, rheology

KAKAO TOZU İLE AROMATİZE EDİLMİŞ GELENEKSEL SALEP İÇECEĞİNİN REOLOJİK ÖZELLİKLERİ

Özet
Bu çalışmada kakao tozu ile aromatize edilmiş geleneksel salep içeceğinin reolojik özellikleri belirlenmiştir. Kakaolu salep içeceği, süt, şeker ve salepten oluşan salep içeceğine farklı oranlarda (%1, 2 ve 3) kakao tozu ilavesi ile hazırlanmıştır. Örneklerin görünür viskoziteleri 3 farklı sıcaklıkta kesme kontrollü reometre ile belirlenmiştir. Salep içeceklerinin kıvam katsayısı ve akış davranış indeksi değerleri Üslü Yasa modeli ile hesaplanmıştır. Bütün örnekler Newton tipi olmayan pseudoplastik tipi akış davranışı sergilemiş ve görünür viskozite değerleri artan kesme hızı ile azalmıştır. Ayrıca, bütün ölçüm sıcaklıklarında, örneklerin görünür viskoziteleri ilave edilen kakao tozu konsantrasyonu ile birlikte artmış, artan sıcaklık karşısında ise azalma göstermiştir. Örneklerin akış davranış indeksi ve kıvam katsayısı değerleri sırasıyla 0.231-0.326 ve 7.365-21.277 Pa.sn aralığında bulunmuştur. Viskozitenin sıcaklığa bağımlılığı Arrhenius eşitliği ile tanımlanmış ve aktivasyon enerjisi 3.26-17.38 kJ/mol aralığında hesaplanmıştır.

Anahtar kelimeler: Salep, kakao tozu, reoloji

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INTRODUCTION

Salep (from Orchidaceae family) is a food ingredient used for different purposes in food formulations and obtained by milling of dried tubers of wild orchids. It is in powder form, white colored and generally used for the traditional production of salep drink and Kahramanmaraş type ice cream in Turkey (1). Salep contains glucomannan and starch as well as some minerals and water (2). Salep is mostly used in food formulations as a stabilizing agent in food technology due to its strong thickening ability when incorporated into the solutions. It is also preferred for its characteristic flavor which plays an important role in the sensory properties of the final product. Salep drink is a traditional beverage prepared by boiling milk with salep powder and sugar in Turkey. It is a hot drink and generally consumed in winters. The salep drink is preferred by consumers from all ages.

Cocoa beans are the fruit of plant *Theobroma cocoa* L. Cocoa powder is produced from cocoa beans by some technological processes and commonly used in the formulation of chocolate as a basic ingredient. Generally chocolate contains varying percentages of cocoa products like cocoa liquor, cocoa butter, cocoa solids. For that reason, cocoa powder is very important ingredient in food formulations, particularly for chocolates and products like pudding and ice cream (3). In general, cocoa products such as confectioneries and pudding are highly preferred by young consumers and the addition of cocoa powder into a food formulation makes the product more appealing for the young consumers because of its desirable flavor and color. For that reason, to make salep drink appealing for especially young consumers, salep drink can be flavored with addition of cocoa powder.

Rheology is the study dealing with the deformation and flow of product under strain. In food technology, the science of rheology helps to understand how food structure responds to applied force and deformation (4). Knowledge of the rheological properties of liquids and semi-solid foods is very important tool in the calculation of process parameters and quality control of the products. The rheological characteristic is also an indicator of the product's sensory quality for the beverages (5). The calculations in the processes involving fluid flows such as pump sizing, pump type and power requirements, extraction or filtration, necessitates the knowledge of rheological data and the rheology of the products like beverages (6). Liquids are divided into two categories in terms of the rheological characteristics as Newtonian and non-Newtonian fluids. Viscosity of samples is not dependent on shear rate in Newtonian fluids, but it decreases with increasing shear rate in non-Newtonian fluids. Some models such as Newton, Herschel-Bulkley and Power Law are used to characterize the rheological properties of liquid food products (5). There are a lot of studies in the literature related to rheological characteristics of foods, for example boza (7), ayran (8), pekmez (9), honey (10), ice cream (11) and chocolate milk (12).

In this study, the rheological properties of hot salep beverage flavored with cocoa powder were investigated, and the applicability of empirical power-law model to characterize the rheology of the product was determined.

MATERIALS AND METHODS

Materials

Powder salep, sugar and cocoa used as ingredients for the preparation of salep drink were purchased from Özselamoglu Food Co. (Kayseri, Turkey) and milk (full fat) was bought from AYNES milk plant (AYNES Milk Products Ltd. Co. Denizli, Turkey).

Methods

Sample preparation

For the preparation of the salep drink flavored with cocoa powder, 100 ml milk was heated up to 60 ^{o}C and then 2 g of sugar was incorporated into the milk and vigorously stirred on a hot plate (Yellowline MST, Germany). After that, at 65 ^{o}C cocoa powder (1%, 2% and 3%) and at 70 ^{o}C, 0.75 g salep were added into the milk and sugar mixture. Afterwards, the mixture was pasteurized at 75 ^{o}C for 1 min and cooled down to room temperature before analyses were carried out.

Rheological measurements

For the determination of rheological properties, a controlled stress/strain rheometer (Rheostress 1, Thermo-Haake, Karlsruhe, Germany) was utilized. The temperature of sample was carefully controlled using a temperature-control unit (Haake, Karlsruhe, Germany) accoupled with the rheometer. A cone and plate configuration was used, with a cone radius of 35 mm and the gap between the cone and plate was set at 1.00 mm. Measurements were performed over a shear rate range of 1–100 s^{-1} at different temperatures (10, 20 and 30 °C). The sample with the exact amount of 0.85 mL was placed between the cone and plate by a micropipette, and the viscosity and shear stress parameters of the samples were measured as a function of shear rate. The data were fitted to Power law model using Rheowin Data Manager (Version 2.96) Software;

$$\eta_a = K\dot{\gamma}^{n-1} \tag{1}$$

where η_a is the apparent viscosity (Pa s), K is the consistency index (Pa.s^n), $\dot{\gamma}$ is shear rate (s^{-1}) and n dimensionless is flow behavior index. Arrhenius equation was used for the description of temperature effect on the apparent viscosity,

$$\eta = \eta_0 e^{(Ea/RT)} \tag{2}$$

where, η_0 is the constant, Ea is the activation energy (J/mole) R is the universal gas constant (8.314 J/kg K) and T is the absolute temperature (K) . The activation energy was obtained by a linear plot of ln (η) versus (1/T). The mean absolute percentage error (MAPE) was determined with the following equation in which the deviance of observed viscosity value from the calculated viscosity using Arrhenius model.

$$MAPE = \frac{100}{n}\sum[(Y_o - Y_c)Y_c)] \tag{3}$$

where Y_o is the observed apparent viscosity value, Y_c is the calculated viscosity value by Arrhenius equation and n is the number of pairs.

Statistical Analysis

Statistical analysis were conducted using the SAS (13) system. The effect of independent variables on the dependent variable was determined using one way and two way Analysis of Variance (ANOVA) with the general linear model (GLM) procedure. Duncan test was used for the determination of differences between mean values.

RESULTS AND DISCUSSIONS

The apparent viscosity of salep drink samples at constant temperature (20 °C) is illustrated in Figure 1. As shown in the figure, the control and salep drink flavored with cocoa powder displayed a non-Newtonian pseudoplastic flow behavior in which the apparent viscosity values of samples decreased with increasing shear rate. Similar results were reported in the literature for different dairy products in terms of flow behavior. For example, Telcioğlu and Kayacier (14) investigated the rheological properties of reduced calorie salep drink and found that the all samples showed a pseudoplastic behavior. Similarly, Dogan and Kayacier (5) reported a pseudoplastic flow behavior for the reconstitued hot salep beverages. Additionaly the apparent viscosity was a function of the amount of cocoa powder added into the sample. It increased with increasing cocoa powder content. An increase in apparent viscosity with increasing cocoa powder in salep drink would be related to higher dry matter content of sample containing cocoa powder. The approximate shear rate in mouth is generally considered as 55 s^{-1} and at that shear rate, the lowest apparent viscosity (0.53 Pa.s) was observed for the control sample, while sample flavored with 3% cocoa powder had the highest apparent viscosity (0.98 Pa.s). The apparent viscosity of control salep drink as a function of shear rate at different temperatures is shown in Figure 2. As expected, the apparent viscosity of samples decreased with increasing temperature. As shown in the figure, the highest value was observed at 10 °C while the lowest at 30 °C. The analysis of varience results revealed that the effect of temperature on the apparent viscosity was significant (P<0.05) at the shear rate of 54.2 s-1.

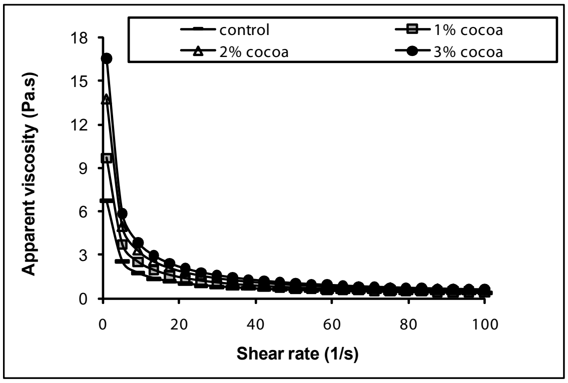

Figure 1. Apparent viscosity of salep drink samples versus shear rate at constant temperature (20 °C)

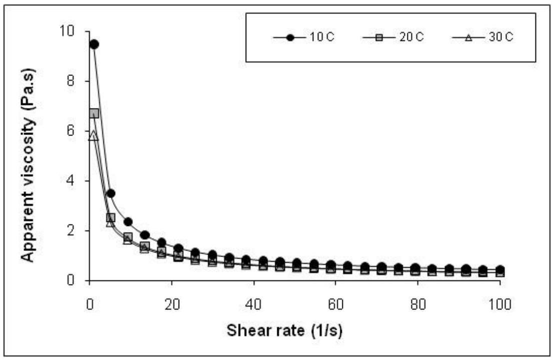

Figure 2. Variations of apparent viscosity of control samples with increased temperature.

The consistency coefficient (K) and flow behavior index of samples (n) was described by using the Equation (1). Power law parameters and coefficient of determination of all samples are given in Table 1. As can be seen in Table 1, the highest consistency coefficient was determined for the salep drink with highest cocoa powder incorporation, while the lowest value was recorded for the control samples at all temperatures. At 20 °C, the lowest K value was recorded for the control sample as 8.083 $P^a.s^n$ while the highest K value was 20.953 $P^a.s^n$ for the salep drink flavored with 3% cocoa powder. K values decreased with increasing temperature and increased with increasing the amount of cocoa powder incorporated into salep drink. n of all samples was found to be less than unity indicating a pseudoplastic behavior.

Table 1. The power law parameters of samples

Sample	Temp. (°C)	K ($Pa.s^n$)	n	R^2
Control	10	11.527	0.292	0.998
	20	8.083	0.320	1.000
	30	7.365	0.326	0.998
1% cocoa	10	13.880	0.267	1.000
	20	12.994	0.268	0.995
	30	11.830	0.270	0.990
2% cocoa	10	18.259	0.250	0.998
	20	17.610	0.259	0.995
	30	15.856	0.265	0.993
3% cocoa	10	21.277	0.231	0.995
	20	20.953	0.232	0.993
	30	16.345	0.238	0.991

The n values increased with increasing measurement temperature as well as the cocoa amount added in the salep drink. The coefficients of determination were closed to 1 which means the good fit for the experimental data and the used model for description of flow. According to the analysis of variance, the difference among the K and n values was statistically significant ($P<0.05$). Dogan and Kayacier (5) found that the consistency coefficient and flow behavior index of reconstituted hot salep beverage prepared with water or milk 0.1-1.453 $Pa.s^n$ and 0.25-0.57 respectively.

The activation energy and coefficient of determination for each samples at three different shear rates were presented in Table 2. At the shear rate of 54.2 s^{-1}, the activation energy was increased with increasing the amount of cocoa powder incorporated into salep drink except for control samples. The highest activation energy value was observed in control samples (10.49 kJ/mole) while the lowest value in salep drink flavored with 1% cocoa powder (3.62 kJ/mole) at the shear rate of 54.2 s^{-1}. Activation energy indicates the sensitivity of the sample viscosity to the temperature change. If Ea is high, it means that the sample is relatively more sensitive to the temperature variations. The calculated viscosity values at 54.2 s^{-1} using Equation (2) were also superimposed in Figure 3. For all samples the mean absolute percentage error was below 1% which indicates that the determined values in this study have a good fit to the model (Table 2). The mean absolute percentage error for all samples was in the range of 0.13-0.69.

Table 2. Arrhenius model constants of salep drink samples at different shear rates

Sample	($\dot{\gamma}$ s^{-1})	h_o (Pa.s)	E_a (kJ/mole)	R^2	MAPE
Control	1.0	$5.69x10^{-3}$	17.38	0.951	0.62
	54.2	$7.52x10^{-3}$	10.49	0.904	0.52
	100	$3.26x10^{-3}$	10.34	0.841	0.69
1% cocoa	1.0	$3.27x10^{-1}$	8.31	0.974	0.21
	54.2	$1.55x10^{-1}$	3.62	0.875	0.21
	100	$1.14x10^{-1}$	3.26	0.938	0.13
2% cocoa	1.0	$7.16x10^{-1}$	7.06	0.826	0.50
	54.2	$9.43x10^{-2}$	5.39	0.892	0.29
	100	$4.91x10^{-2}$	5.87	0.948	0.21
3% cocoa	1.0	$1.70x10^{-1}$	10.98	0.887	0.61
	54.2	$3.20x10^{-2}$	8.15	0.862	0.51
	100	$1.51x10^{-2}$	8.80	0.999	0.42

CONCLUSIONS

In this study the effects of cocoa powder incorporation at different concentrations into salep drink on the rheological characteristics of final product were determined. It was found that salep beverage flavored with cocoa powder exhibited a pseudoplastic behavior.

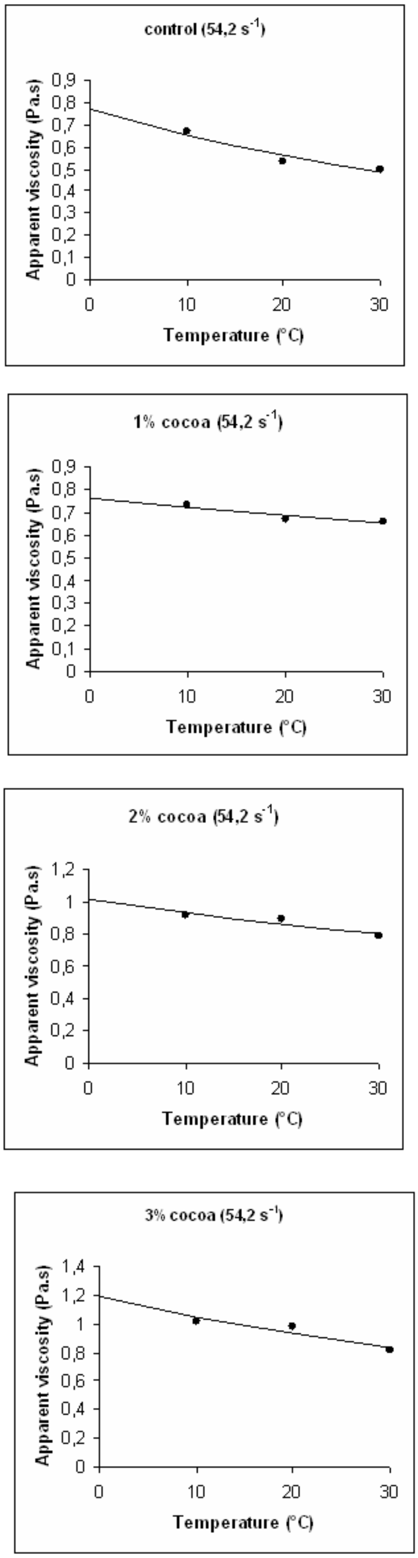

Figure 3. Effect of temperature on the apparent viscosity of salep samples with observed and predicted values at constant shear rate (54.2 s^{-1})

Apparent viscosity and consistency coefficient of samples increased with increasing amount of cocoa powder in salep drink. The activation energy calculated with Arrhenius model revealed that the viscosity of control sample was the most sensitive to temperature change at any shear rate. It is known that rheological properties of liquid affect the consumer preferences; hence, the results of this study could be used for the industrial production of salep drink flavored with cocoa powder.

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