THE EFFECT OF ACOUSTIC ENERGY ON VISCOSITY AND SERUM SEPARATION OF TRADITIONAL AYRAN, A TURKISH YOGURT DRINK

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Abstract

The effect of acoustic energy on the rheological behaviour and serum separation during storage of traditional Ayran, which is a mixture of yogurt, water and salt, was investigated. Ayran samples were prepared by the addition of water at a level of 40% (w/w) and salt at a level of 1% (w/w) and stored at 4 °C. They were sonicated for two and four minutes using an ultrasonic generator at a frequency of 20 kHz. The ultrasonic amplitudes used were 40% (22.91W), 60% (33.38W) and 80% (44.54W). Viscosity was measured using a rotational viscometer at the speed of 20, 30, 50, 60, 100 and 200 rpm. The highest apparent viscosity in Ayran was obtained at 44.54 W power level for 4 minutes. In addition, it was obtained that acoustic energy had a significant effect on the serum separation of Ayran. An empirical power-law model was used to describe the rheological behaviour of Ayran samples with regression coefficients between 0.891 and 0.997. Ayran exhibited a pseudoplastic behaviour, non-Newtonian.

Keywords: Acoustic energy, traditional Ayran, viscosity, serum separation

GELENEKSEL AYRANIN VİSKOZİTE VE SERUM AYRILMASI ÜZERİNE AKUSTİK ENERJİNİN ETKİSİ

Özet

Geleneksel Ayranın reolojik davranışları ve depolama sonrası serum ayrılması üzerine akustik enerjinin etkisi araştırıldı. Ayran örnekleri yoğurda %40 (w/w) su ve %1 tuz (w/w) ilave edilerek hazırlandı. Elde edilen Ayranlara 20kHz frekansta çalışan bir ultrases işlemcisiyle 2 ve 4 dakika ultrases işlemi uygulandı. Ultrases genlik seviyesi %40 (22.91W), %60 (33.38W) ve %80 (44.54W) olarak kullanıldı. Viskozite 20, 30, 50, 60, 100, 200 rpm'de rotasyonel viskozimetre kullanılarak ölçüldü. En yüksek viskozite değeri 4 dakikalık işlem süresinde 44.54 güç seviyesinde elde edildi. Ayrıca, akustik enerjinin ayranın serum ayrılması üzerine önemli bir etkiye sahip olduğu gözlendi. Ayranın reolojik özelliklerini tanımlamak için deneysel power-law modeli kullanıldı. Modele ait regresyon katsayıları 0.891 ve 0.997 arasında değiştiği gözlendi. Ayran Newtoniyal olmayan pseudoplastik bir davranış sergiledi.

Anahtar kelimeler: Akustik enerji, geleneksel Ayran, viskozite, serum ayrılması

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INTRODUCTION

Ayran, made by diluting yogurt with water is traditionally produced by adding water to yogurt at a level of 30–50% and table salt at a maximum level of 1%. Table salt is generally added to enhance the taste of Ayran. In the industrial manufacture of Ayran, milk with adjusted dry matter content is fermented using exopolysaccharide -producing cultures, and the viscous curd obtained is further diluted with salt and water (1). Cooling after manufacture is important in order to stop fermentation and prevent further acidity development.

The quality of Ayran deteriorates during storage due to acidity development and serum separation (2), since Ayran tends to become unstable due to its low pH (approximate pH 4.2). The optimum consistency for pleasant mouth feeling and no serum separation during storage are the desired quality criteria by consumers of Ayran (3). The failure of whey-based beverages to perform well in the market is related to serum separation (4).

The textural and rheological properties of Ayran have been studied up to a point in the literature. Knowledge of rheological properties is important for foods, such as fermented dairy products, in the design of flow processes, processing, storage and quality control and in predicting the texture of foods (2, 5). Dairy products rarely obey Newton's law of viscosity; they generally exhibit non-Newtonian behaviour, such as shear thinning and are generally described by the power-law model (1, 6-8).

A common denominator of fermented milk drinks like Ayran is their low pH and low viscosity, which results in sedimentation problems due to aggregation of milk protein (9). To prevent or reduce the aggregation of milk protein, a stable emulsion is necessary. Emulsions, a dispersion of two immiscible liquids, one of which is dispersed into the other in the form of fine droplets or particles, are unstable systems. Energy is needed to disperse a liquid phase (dispersed phase) in the form of small droplets in a second phase (continuous phase) (10). Therefore, ultrasound, defined as waves with a higher frequency, can be extremely useful due to their transfer of acoustic energy to the medium, and the resultant shock wave by acoustic energy can provide extremely efficient mixing of the two layers. This technique causes alteration of viscosity dependent on the intensity of acoustic energy. Ultrasound has recently become an alternative method of killing microorganisms, inactivating enzymes, homogenization, extraction, crystallisation, dewatering, degassing, particle size reduction, and especially emulsification (11-13), and has been known to allow formation of very fine emulsions (14). The advantages of acoustic energy includes the use of less surfactant and the production of an emulsion that is more homogeneous compared to a mechanical process (15). Our goal was to investigate the effect of acoustic energy at different amplitude (power) levels on viscosity and serum separation of Ayran, manufactured using the traditional method.

MATERIALS and METHODS

Production of Traditional Ayran

Ayran samples were produced in the laboratory using the traditional method of mixing yogurt with drinking water and table salt, which are added at levels of 40% (w/w) and 1% (w/w), respectively (1). The samples were adjusted to 9.8% of the total solid. Then, Ayran samples were mixed with an Ultra Turrax homogeniser (Model T25 basic, Ika-Werke, Germany) at 9,500rpm for 30 seconds and stored at 4 °C. The samples were prepared in duplicate for analyses. The production conditions of yogurt from thermal treatment (5 minutes in 95 °C), vacuum (5 minutes), fermentation (3 hours in 45 °C and last pH: 4.6) and cooling (last pH: 4.2). Total solids (16) and fat (17) contents of yogurt was determined as 14.8% and 1.5%, respectively. Production conditions of the yogurt were defined as a dairy factory (Palandöken Süt Ürünleri A.Ş., Erzurum).

Ultrasonic Treatment

An ultrasonic generator (Model 500-watt ultrasonic processors, Cole-Parmer, USA), equipped with a 19mm diameter cylindrical tip and working at a constant frequency (20kHz), was used to treat

150ml of Ayran for each treatment. This generator converts 50Hz line voltage to a high frequency electrical power of 20kHz. The ultrasound probe was immersed in the Ayran at a depth of approximately 3cm within beaker of 200ml. The experiment was carried out using different amplitude levels (40, 60 and 80%). Ultrasound power levels corresponding amplitudes were calculated to 22.91, 33.38 and 44.54 W, respectively using the calorimetric method (18). Exposure times were 2 and 4 minutes at each amplitude level. Control samples were untreated Ayran.

Viscosity

The viscosity (mPa s) of Ayran samples after 1 day of storage at 4°C was measured using a rotational viscometer (Fungilab, Viscostar, Spain) at the speed of 20, 30, 50, 60, 100 and 200rpm. Three readings were taken per sample at 10 second intervals. A 150ml beaker was used to take viscosity measurements. Several rheological models have been employed to take data on acidified milk drinks. The rheological behaviour of Ayran was described by the power law model (19):

$$\eta_a = K\,\Upsilon^{(n-1)} \qquad \text{(Eq 1)}$$

where η_a is the apparent viscosity (mPa s^n), *K* the consistency index (mPa sn), Υ the shear rate (s^{-1}), *n* the flow behaviour index (dimensionless). Eq 1 was analysed using linear regression in order to obtain the flow behaviour index (*n*) and consistency index (*K*) values from plots of log apparent viscosity versus log shear rate. Statistical analyses were carried out using the SPSS software package (version 13). All values were considered statistically significant ($P< 0.05$).

Serum Separation

Ayran samples were placed in 50 ml graded cylinders. After storage for 15 days at 4°C, the volume of the layer of clear serum at the top on day 15 was recorded as an indication of instability (2). Measurements taken performed in duplicate.

RESULTS and DISCUSSION

Viscosity

Acoustic energy caused a significant increase in the apparent viscosity of Ayran. The apparent viscosity of Ayran increased with the increasing power levels accompanied with an increase in the consistency coefficient (Table 1). The increase of the apparent viscosity and consistency coefficient may be explained with the ability of newly formed globules of whey proteins to bind a greater amount of water, since the hydrophilic parts of amino acids are located on the outer part of protein globule (20). In addition, the volume fraction of the available casein particles increases with the use of acoustic energy, so the viscosity of Ayran increases (21). The highest apparent viscosity and consistency coefficient in Ayran were obtained at a 44.54 W power level for 4 minutes. Similar results were also obtained in other studies (21).

The apparent viscosity of Ayran decreased with the increasing shear rate, which indicates non-Newtonian behaviour with shear-thinning (Fig 1). The rheological behaviour of Ayran was accurately explained by the power-law model (Eq 1) with high regression coefficients ranged from 0.891 to 0.997. From the presented data, it

Table 1. Rheological properties and serum separation of traditional Ayrans at different amplitude levels of acoustic energy

Amplitude Levels and Exposure times	Apparent Viscosity (mPas)	Consistency Coefficient (*K* mPa s^n)	Flow Behaviour Index (*n*)	Regression Coefficients (*r*)
Control	38	14.00	0.260	0.997
40% - 2 min	30	11.62	0.245	0.987
40% - 4 min	74	183.5	0.221	0.891
60% - 2 min	84	336.5	0.337	0.940
60% - 4 min	142	1170.3	0.514	0.961
80% - 2 min	272	4154.7	0.689	0.991
80% - 4 min	292	5388.4	0.721	0.974

can be concluded that Ayran exhibited a pseudoplastic fluid, with a non-Newtonian character, since the values of the flow behaviour index (n), a measure of the departure from Newtonian flow (22), ranged between 0 and 1. Ayran samples sold in retail markets in Turkey have been found to be non-Newtonian pseud oplastic fluids, with thixotropy in some samples modelled with the power law model (5). The power-law model has also been used for cultured dairy products by other researchers (8, 23).

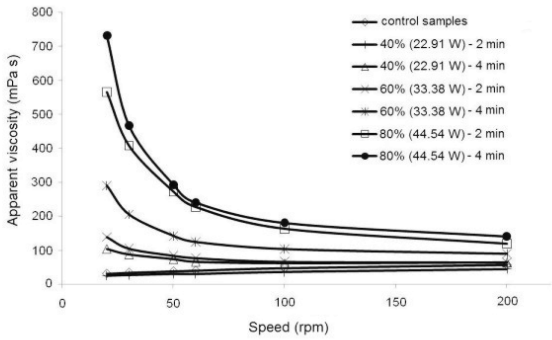

Fig 1. The flow behaviour of traditional Ayran

Serum separation

Serum separation is a common phenomenon occurring in acidified dairy drinks and results in the sedimentation of large particles at the bottom or the formation of a serum layer at the top due to aggregation and sedimentation of casing particles during storage (24). The data obtained via volumetric measurements indicated that acoustic energy had a significant effect on the serum separation of Ayran. The most effective result is obtained at the highest power level (44.54 W) and the longest exposure time (4 minutes). Sonicated samples obtained significantly ($P<0.05$) lower serum separation than the control sample at all exposure times. This effect was more pronounced with increased amplitude (Fig. 2).

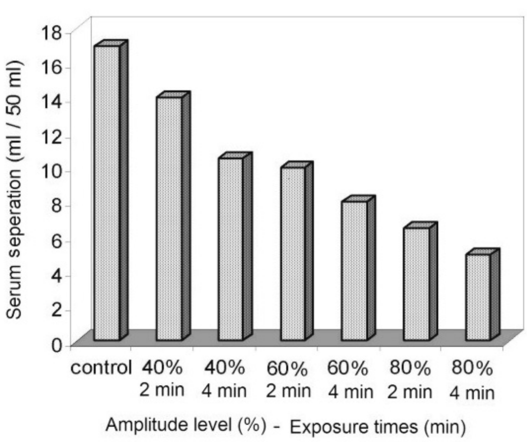

Fig. 2. The effect of acoustic energy on serum separation of traditional Ayran

The effect of acoustic energy on serum separation can be attributed to the cavitation phenomenon. During acoustic energy treatment, the main active force is mechanical in nature, resulting in the formation and implosion of bubbles in a liquid (cavitation) (25). Imploding cavitation bubbles cause intensive shock waves in the medium and collapse near the surface of the phase boundary layer of two immiscible liquids (13). This may supply extremely effective mixing of two immiscible liquids in association with finely dispersed emulsions and thereby prevent serum separation. Longer sonication times produce finer emulsions, since a larger amount of energy is provided to the liquid medium (11).

CONCLUSIONS

It was found that ultrasound, a potential alternative to conventional processes, produced traditional Ayran with a higher stability. Increasing the viscosity and decreasing serum separation in Ayran were found to be possible by using acoustic energy at certain power levels and exposure times. The rheological behaviour of Ayran was found to be most adequately described by the power-law model. It can be concluded that Ayran was a pseudoplastic fluid, of a non-Newtonian shear thinning type.

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