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THE INTERNATIONAL SYMPOSIUM ON

FOOD RHEOLOGY & TEXTURE

CONTENTS

TALKS

Gels, Emulsions, Quality Criteria

Food groups: Dough, Dairy, Poultry, Confectionary

Traditional foods/drinks

Oral presentations from companies

POSTERS

Rheological-textural methods

Gels, Interfaces, Emulsions

Traditional foods/drinks

ORAL PRESENTATIONS

OPENING LECTURE

CHALLENGES IN RELATING RHEOLOGICAL PROPERTIES OF FOODS TO THEIR PERCEIVED TEXTURE

Prof. Dr. Micha PELEG

University of Massachusetts, Department of Food Science, Amherst, MA, USA

There are numerous mechanical methods to evaluate the texture of solid, semi-solid and liquid foods, and a wide range of instruments from very simple to highly sophisticated, which include state-of-the-art rheometers. Yet, even with the latter there are some unresolved issues concerning what is actually measured and how it is related to sensory textural attributes.

Apart from the obvious differences between the construction materials and shape of a man made testing machines and those of humans' mouth and fingers, there are also semantic issues, qualitative differences between a rigid testing machine and soft tissues with imbedded mechanoreceptors, difficulty to perceive mechanical stimuli in isolation, and problems with the interpretation of force-time records. Several of these issues and their implications will be addressed by demonstrating certain salient characteristics of "soft machines mechanics." Sources of common problems with mechanical testing of solid foods will also highlighted, and sources of artifacts in viscosity measurements of semi-solid foods, associated with slip and premature destruction of their structure, will be demonstrated.

A first presented case study is a demonstration that the major problems of instumental evaluation of semi-liquid foods' consistency can be avoided by using "lubricated squeezing flow" instead of shear viscometry. This method enables to test semi-liquid foods practically intact, including foams, gels and foods having suspended paricles, and samples differing *only* in their rheological properties but not in taste or appearance.

The second case is that of the cellular brittle cereals and snacks whose force-diplacement curves are irregular and irreproducible. It will be shown how one can extract useful inforamtion from such curves, and demonstrate that the "crunchiness" of such foods can be quantified in terms of the juggedness of their mechanical signatures expressed in terms of an apparent fractal dimension. We will also demonstrate that human perceive "crunchiness" separately from "hardness" when such foods become "soggy" by moistre sorpotion.

Key Words: *rheology, perceived texture, food*

KEYNOTE SPEAK

NON-LINEAR LARGE AMPLITUDE OSCILLATORY SHEAR (LAOS) PROPERTIES OF FOOD MATERIALS WITH DIFFERENT STRUCTURAL PROPERTIES AND THE SIGNIFICANCE OF NON-LINEAR LAOS PROPERTIES

Prof. Dr. Jozef L. KOKINI

Purdue University, Department of Food Science, West Lafayette, Indiana, USA

The rheological behavior of semisolid foods under large amplitude oscillatory shear (LAOS) can offer detailed understanding of structural changes occurring during processing and consumption. This presentation focuses on a detailed description of LAOS measurements (theory, testing method, data interpretation, and corrections), its application on food systems with different core structures ranging from dilute dispersions to gels to foams to emulsions to soft elastic networks, to yogurt. Type of stress responses for different rheological behavior, Lissajous-Bowditch curves and the resulting LAOS parameters (e_3/e_1 , v_3/v_1 ,G'_M, G'_L, η'_M, η'_L, *S* and *T*), were used to understand the structural changes in all of these foods. Details of this methodology and the learnings that result from them will be discussed in detail and compared with information obtained using small amplitude oscillatory measurements. The interpretation of the data in terms of predicting quality, texture and changes during processing will be discussed.

Key Words: *LAOS, Lissajous-Bowditch curves, non-linear*

KEYNOTE SPEAK

RHEOLOGY AND DAIRY FOODS

Prof. Dr. Sundaram GUNASEKARAN

University of Wisconsin-Madison, Department of Biological Systems Engineering, Madison, WI, USA

Dairy foods represent one of the oldest and among the most popular categories of foods around the world. From naturally available milk to highly processed various cheeses and other products, rheological properties of dairy foods run the entire gamut from almost Newtonian to nearly Hookean. Thus, the study about rheology of dairy foods hold a special allure for food scientists, technologists, and engineers alike. In this talk, rheology of dairy foods is viewed through the lens of applied rheologists to make the information provides highly relevant and practical for both academicians and dairy industry professionals. Emphasis is placed on elucidating structural underpinnings of complex rheological character of different dairy foods. The effect of compositional factors (fat, proteins, minerals) as well as manufacturing or processing conditions (pH, temperature, ionic strength, ageing, etc.) will be addressed as they affect product viscosity, stiffness, modulus, and viscoelasticity. Rheology of functional properties such as melt, stretch etc. will also be discussed.

Key Words: *dairy foods, rheology*

KEYNOTE SPEAK

HOW RHEOLOGY MAKES A DIFFERENCE IN THE FOOD INDUSTRY

Assoc. Prof. Dr. M. Mehmet AK

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Rheology is the study of the deformation and flow of matter. It is applied in many fields ranging from cosmetics to pharmaceuticals and from polymers to foods. Rheology has strong relevance to the processes applied in the food industry as well as during the consumption of foods. It is my opinion that rheology has not received the attention it deserves from the working food engineers; at least in the Turkish food industry. In this presentation initially, an overview of rheological principles is presented. This is followed by a discussion of different rheological behaviors observed in food products. Then, a stepwise approach based on asking questions is presented to choose a viscometer or rheometer that meets the needs. Since this presentation is oriented towards the young food engineers working in the industry a few real-life examples are shared to demonstrate the utility of rheology in practice. The selected examples intended to show how rheology can help food engineers in identifying problems in incoming materials, in avoiding production failures that result in wastage, and in designing new products with desired properties.

Key Words: *rheology, food industry, quality*

RHEOLOGICAL-TEXTURAL METHODS

LINEAR AND NON-LINEAR RHEOLOGICAL BEHAVIOR OF MAYONNAISE

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ABSTRACT

The determination of rheological properties of emulsions has a key importance in many applications due to the reflection of its rheological behavior. In this study, the linear and nonlinear rheology of a commercial mayonnaise (Heinz) were studied in the strain range of 0.01-200% at 1 rad/s. The effect of the number of cycles at each point of strain was investigated by increasing the number of cycles (5, 25 and 50 cycles) at each point of strain. The comparison of strain sweeps and the extracted data has been done. The elastic and viscous components of Lissajous-Bowditch curves in SAOS, MAOS and LAOS regions have shown that there is intracycle resistance to imposed repeating strain in SAOS and MAOS regions. The variations of LAOS parameters (e_3/e_1 , v_3/v_1 ,G'_M, G'_L, η'_M, η'_L, *S* and *T*) with respect to strain reveal that even though mayonnaise has a shear thinning flow behavior according to G' and G'' observed in strain sweeps, it shows intracycle strain stiffening and shear thickening behavior in SAOS and MAOS instar cycle strain softening and shear thinning in LAOS region.

Key Words: *mayonnaise, non-linear rheology, small and large amplitude oscillatory shear flow*

INTRODUCTION

Emulsions are two-phase mixtures containing two immiscible liquids in which one phase is dispersed in the other one in form of droplets. Emulsions can be oil-in-water (O/W) or water-in-oil (W/O) type of emulsions and has been gained a great interest due to numerous different type of industrial applications such as food materials, cosmetics, pharmaceuticals, agrochemicals and etc. The relation between the structural changes and shear has been tried to reveal by study of small amplitude oscillatory shear flow. While small deformation properties have been very useful in learning about the relationship between their structure and deformation behaviors these tests do not provide information which is particularly consistent with the large deformation environment in food processing and in consumption of foods leading to their sensory perception.

Structure dependent rheological parameters in non-linear region with the advent of new theories leading to rigorous rheological properties characterizing non-linear behavior through the remarkable work of Ewolt and McKinley [1] where the time dependence in the non-linear region is effectively simulated using Fourier transforms and the strain dependence has been successfully de-convoluted using Chebyshev polynomials, new tools exist to probe the rheology of these materials much more in depth than was possible in the past.

The recent researches on non-linear rheological behavior of food materials (dough, tomato paste, chocolate, mashed potato, egg white foams) have shown that very rich structural changes can be captured by LAOS analysis through non-linear shear flow [2, 8]. This hidden knowledge might be very useful in many applications such as mixing, homogenization, storage, transportation on pipelines, handling etc.

MATERIALS and METHODS

The linear and nonlinear rheology of a commercial mayonnaise (Heinz) were studied in the strain range of 0.01-200% at 1 rad/s. The rheological experiments were performed using controlled strain conditions by a stress controlled Discovery Hybrid Rheometer DHR3 (TA Instruments). The strain input produced by using a stress-controlled rheometer is identical with the strain input produced from a strain-controlled rheometer [9]. A fresh sample was used for each measurement and was allowed to relax in the parallel plate geometry until the normal force was lower than 1 N prior to each measurement. The sample (~2-3 ml) was placed onto measurement space, trimmed at trim position (2.2 mm of gap) with a razor blade, covered by vegetable oil to eliminated drying during measurement from lateral surface prior to rheological measurements. The gap kept 2 mm during measurement. 40 mm parallel plate fixture with a hatched surface for strain sweep was used.

The importance of number of cycles at each imposed strain rises due to progressive change in structure of material developed by imposed strain. Its distinctive effect on data collected during measurement was investigated by increasing the number of cycles (5, 25 and 50 cycles). The comparison of strain sweeps and the extracted data was aimed. The first step of data analysis is transformation of data from time domain to frequency domain by Fourier transformation. Later, the extraction of harmonics, recasting of both harmonics and sinusoidal waves and determination of LAOS parameters were done by using the software of TA instruments.

RESULTS and DISCUSSION

The small and large amplitude rheological behavior of mayonnaise was investigated in order to develop a more detailed understanding when the material is subjected to large strains in comparison to small strain where all materials display linear behavior. The storage modulus (G') showed a sharp decrease in LAOS indicating strong structural changes within the fluid as the strain increased from the linear to the non-linear region (at 1 rad/s and 4 cycles at each point of strain). The apparent long linear viscoelastic region (LVER) may be related with the elastic structural network formed by forces which includes the entanglements among the protein segments absorbed at oil-water interface and the interfacial forces exerted by the surface active materials holding the interface together [10]. The strain sweep of mayonnaise has an overshoot in the loss modulus (G'') in the non-linear region. This can be attributed to interaction between oil spheres and the loss of the stacking sequence. When the number of cycles at each point of strain was increased it was observed that G', G'' and tan(δ) were almost the same. Strain sweep results for the mayonnaise samples with different cycles are shown in Figure 1.

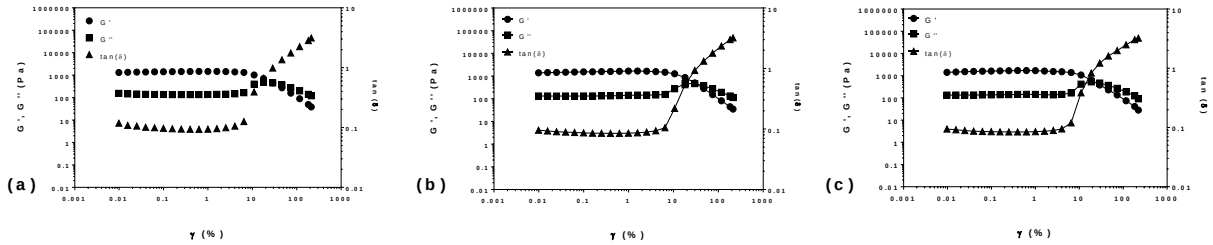

Figure 1. Strain sweeps of mayonnaise with (a) 5 cycles, (b) 25 cycles and (c) 50 cycles at each point of strain at 1 rad/s and 25°C.

After the Fourier transformation and extraction of non-linear structure dependent parameters by using Chebyshev coefficients (LAOS Parameters- e_3/e_1 , v_3/v_1 ,G'_M, G'_L, η'_M, η'_L, S and T) the structural changes experienced by mayonnaise can be seen by Lissajous-Bowditch curves which are plots of stress with respect to strain (elastic perspective) and strain rate (viscous perspective). A viscoelastic solid material shows narrow elliptically shaped curves elastic plane and a circle in viscous plane, which stores most of the given energy and dissipates very little. The areas in curves in elastic and viscous planes show the stored energy and dissipated energy, respectively. However, a viscoelastic liquid material shows a very wide elliptically shaped curves in elastic plane and narrow elliptically shaped curves in viscous plane which dissipates most of the given energy. Figure 2 shows Lissajous-Bowditch curves of mayonnaise at different cycles in small amplitude oscillatory shear flow (SAOS-0.1% of strain) in medium amplitude oscillatory shear flow (MAOS-18% of strain) and large amplitude oscillatory shear flow (LAOS-210% of strain).

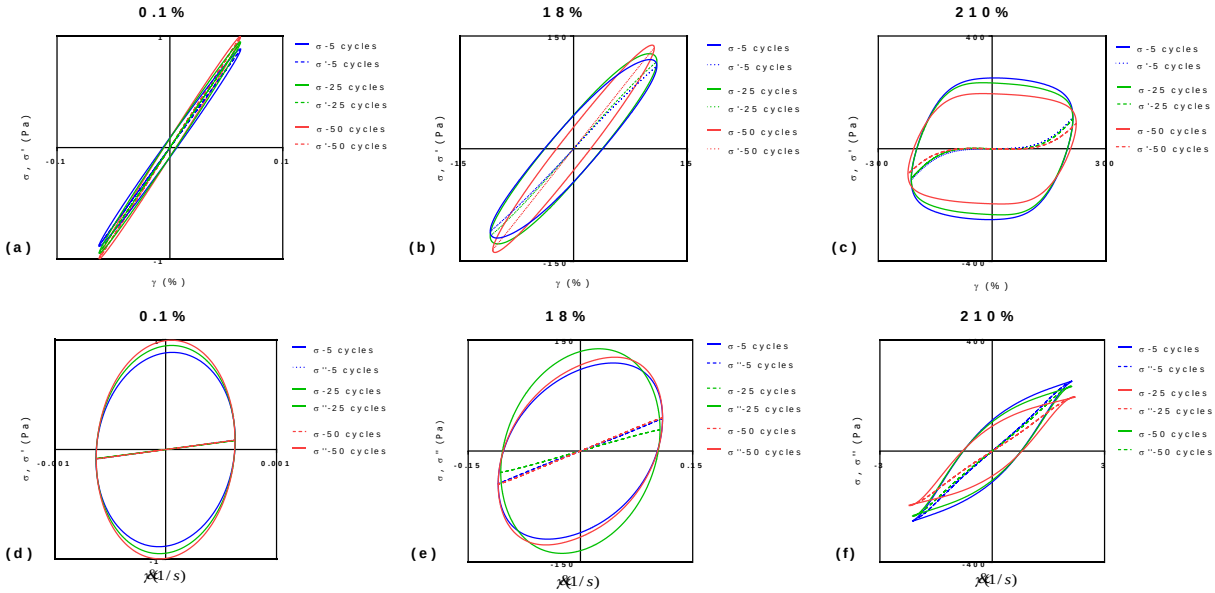

Figure 2. (a, b, c) Elastic and (d, e, f) viscous perspectives of Lissajous-Bowditch curves of mayonnaise at (a) 0.1% , (b) 18% and (c) 210% of strain at different cycles (5, 25 and 50 cycles).

The very narrow elliptical shaped curves in elastic plane and almost a perfect circle in viscous plane in SAOS region showed that mayonnaise became stiffer as the number cycles was increased and there is a counter-clockwise turn at the maximum strain indicating higher resistance to oscillatory movement (strain stiffening). This behavior has reflected in viscous plane as bigger circle as the number of cycles was increased. Similar behavior has been observed in MAOS region. There is a clockwise turn in elastic

plane at higher number of cycles indicating softening of mayonnaise structure in LAOS region. This strain softening behavior accompanied by clockwise turn in viscous plane which indicates shear thinning behavior.

The linear behavior seen in G'_M& G'_L, η'_M&η'_L, and *S*&*T* up to ~10% of strain shows the LVER and there is no non-linearity (Figure 3).

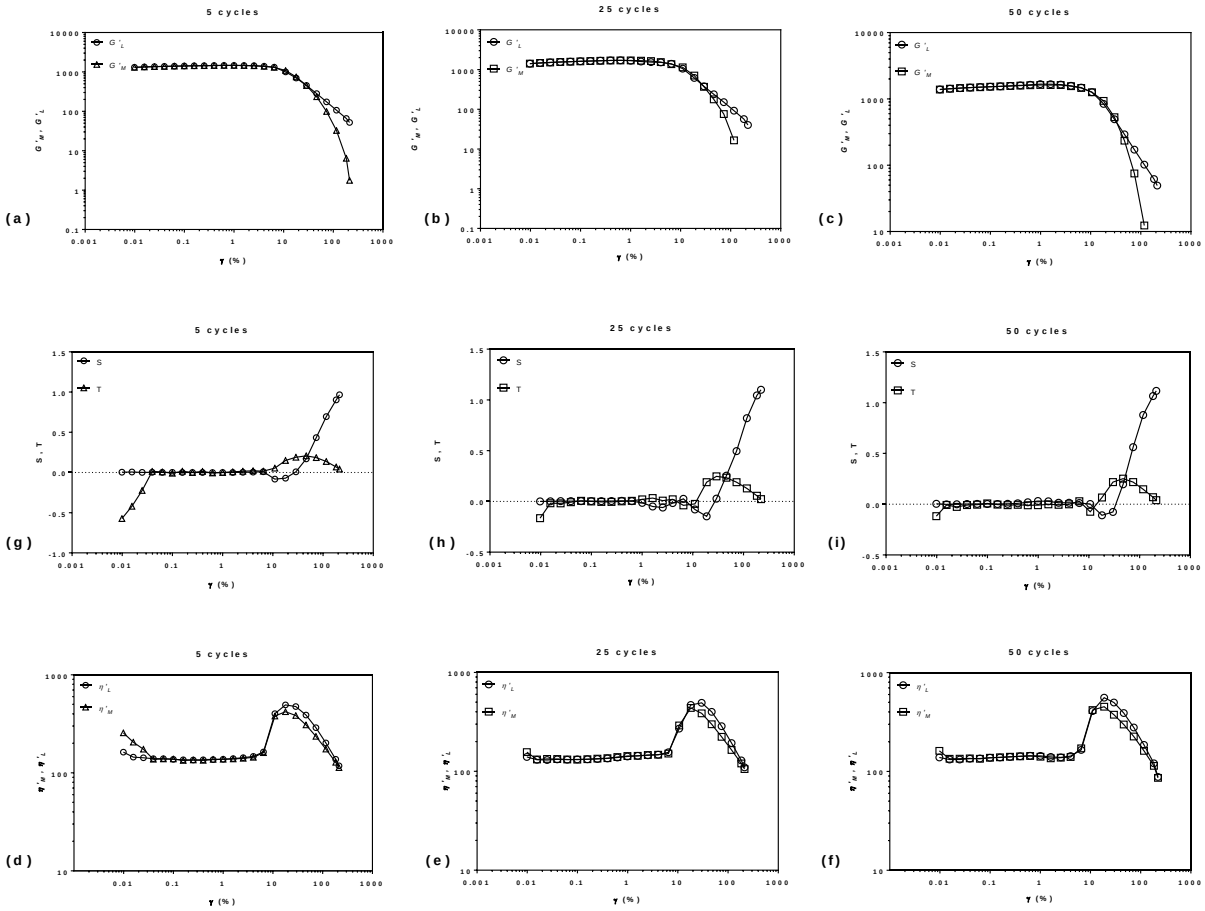

Figure 3. The LAOS parameters (G'_M, G'_L, η'_M, η'_L, *S* and *T*) with respect to strain (%) at different cycles (5, 25 and 50 cycles).

The emergence of non-linear behavior is above 10% of strain and as the number of cycles increased the variations differed. The general trends of G'_M&G'_L, η'_M&η'_L, and *S*&*T* with respect to strain at different number of cycles were the same which implies flexible structure of mayonnaise. The structure became more softened as strain was increased and mayonnaise had lower G'_M& G'_L and they head negative values when strain is higher than 100% of strain. Mayonnaise also showed higher η'_M& η'_L values where it made a maximum (18% of strain). The intracycle viscosities, η'_L and η'_M, were 494 and 420 Pa.s at 5 cycles, 468 and 438 at 25 cycles and 558 and 452 Pa.s at 50 cycles, respectively. Stiffening and thickening ratios were slightly increased with the number of cycles applied meaning the resistance of mayonnaise to the repeating oscillatory shear flow. Hence, even though mayonnaise has a shear thinning flow behavior it also shows intracycle shear stiffening and thickening behavior in SAOS and MAOS and strain softening and shear thinning in LAOS.

CONCLUSION

SAOS is a non-destructive test and it is very useful regarding capturing the relationships between structure and deformation of materials. LAOS captures much deeper and richer information as flow induced structural chagens occur at larger deformations. The non-linearites in non-linear region is observed by Lissajous-Bowditch curves and LAOS parameters (e_3/e_1, v_3/v_1, G'_M, G'_L, η'_M, η'_L, *S* and *T*). Higher number of cycles applied at each point of strain had more influential effect on structural changes in terms of Lissajous-Bowditch curves and LAOS parameters. In SAOS and MAOS regions intracycle strain stiffening and shear thickening were observed. However, when the strain is high enough (~210% of strain) strain softening and shear thinning were observed.

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RHEOLOGICAL-TEXTURAL METHODS

A NEW APPROACH FOR THE DETERMINATION OF CHOCOLATE MELTING POINT WITH RHEOMETER

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ABSTRACT

Chocolate is defined as the unique product obtained from cocoa products and sugars, melts at body temperature while it is solid at room temperature. However the melting point of chocolate is not a fixed value and it depends on several factors such as cocoa butter, cocoa solid, sugar, emulsifiers and addivites. Differential scanning calorimetry method (DSC) is the widely used method for determination of chocolate melting point. Rheometer is an accurate device to measure the solid-liquid behaviour of foods under controlled temperature. Furthermore, rheological behaviour of chocolate is related to its microstructure. In our research, rheometer is used for determination of melting point of solid chocolate for the first time. Rheological measurements were carried out from 10°C to 50°C using rheometer equipped with parallel plate. For this purpose, solid chocolate sample was placed between parallel plates with constant axial force of 50 N. When the chocolate melted with the increase of temperature, the gap value decreased to provide 50 N axial force. From the gap versus temperature graph, starting of sharp decrease in gap showed the melting point of chocolate. Consequently this new robust direct method is a strong alternative to DSC method which indirectly measures the melting temperature by using melting enthalpy of cacao butter crystals. Therefore, the new application area of rheometer was discovered including non-elastic solid foods.

Keywords: *chocolate, rheology, melting, DSC*

RHEOLOGICAL-TEXTURAL METHODS

THERMAL LOOP TEST AS A NOVEL METHOD FOR DETERMINATION OF THE EMULSION STABILITY

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ABSTRACT

Emulsion stability is one of the crucial factor determining the shelf life of the food emulsions and should be identified by reliable methods in short times as far as possible. Physical stability of the food emulsions is determined by visually although several methods have been developed. This method needs a long time and does not provide an accurate result. The fast and practical methods should be required for this aim. Thermal loop test is a suitable method to determine emulsion stability in short period. In this test, the emulsions are subjected to thermal cycles with different numbers. The test simulates temperature fluctuations occurring during processing, production, storage and transportation stages. This study aimed to determine the physical stability of the oil in water emulsions by thermal loop test as a novel method. Five samples with different gum concentrations (0.1-0.5%) were prepared to achive emulsions with low and high physical stability. The samples were subjected to ten thermal cycles from 23 to 45°C in high-temperature stability test and from 5 to 23°C in low-temperature stability test. At every cycle, ten maximum comlex modulus values (G^*) were obtained. In low-temperature stability test, percentage change in G^* of the samples (Δ) were found to be 4.15%, 2.82%, 1.32%, 1.17% and 4.68% for the samples formulated by 0.1% - 0.5% gum concentrations, respectively. In the high-temperature stability test, Δ values were determined as 7.7%, 0.58% and 7.22% for the samples formulated by 0.3%, 0.4% and 0.5% gum concentrations, respectively. In the high-temperature test, dramatic changes were observed in the G^* value for the samples including 0.1% and 0.2% gum. The samples formulated by 0.1% and 0.2%gum concentrations showed low emulsion stability. These results were also be confirmed by visual test and zeta potential measurement. The low zeta (ζ) potential values and phase separation were observed in the weak emulsions. Other emulsions did not show phase separation. This study suggested that thermal loop test could be successfully applied for determination of emulsion stability in short times.

Key Words: *emulsion stability, thermal loop test, complex modulus*

RHEOLOGICAL-TEXTURAL METHODS

RECENT DEVELOPMENTS IN TEST METHODS USED TO EVALUATE FOOD POWDER RHEOLOGY AND CHARACTERIZATION

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ABSTRACT

The rheological properties of food powders have been gaining attention since varying processes and applications related to powders take place during food processing steps such as transportation, storage, production and packaging. Particle properties such as particle shape, particle density, surface characteristics along with bulk powder properties such as powder flowability, bulk powder density, compressibility and caking need to be investigated and characterized to be able to optimize process parameters as well as to design processing lines. The effect of environmental variables such as temperature and humidity on powder rheology is also very important and need to be analyzed. In this work, recent developments in the methods used to evaluate powder rheology have been outlined.

Key Words: *powder rheology, food powders, particle, bulk powder*

GELS

DETECTION OF SOME FUNCTIONAL, GELATION AND VISCOELASTIC CHARACTERISTICS OF CHIA SEEDS (*SALVIA HISPANICA L.*) IN MODEL SYSTEMS

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ABSTRACT

In recent years, chia seeds (*Salvia hispanica L*.) have been regarded as superfoods due to their components such as dietary fibre, phenolics and unsaturated fatty acids. Moreover, their specific feature to form gels with water makes chia seeds also a good functional alternative for industrial use. In this study, the aim was to investigate functional properties such as water and oil retention capacities, swelling power and emulsifying ability for both whole and grinded chia seeds. In this content; gelation properties in different model systems comprising water, sugar and milk under various temperature, concentration and pH conditions were also detected. According to the proximate analyses chia seeds total moisture, fat, protein, ash and carbohydrate contents were found as 6.6%, 34.9%, 21.5%, 4.3%, and 32.7%, respectively. Water retention capacity was 19.2±1.3% and 8.7±1.0%, in seeds and grinded samples, respectively while oil retention capacities were measured as 4.5±0.5% and 4.4±0.4%, in seeds and grinded samples, respectively. Increase in temperature decreased the swelling power, being higher in grinded samples. Increasing effect of pH on gelation was clearer in grinded samples. According to the thermal measurements by DSC gelation started in the range of 20-35ºC with the peaks in the range of 30-44ºC, and the gel structure deterioration started was between 77-82ºC. In the model systems, the maximum viscosity was measured as 12.6±1.1 cP at 24°C, for the model system with whole milk, 10% sugar and 2% chia seeds. Acidity and high temperatures were identified as factors reducing the viscosity. Overall, provided interesting functional insights of this study may support the potential ability of using chia seeds in different food applications, including the dairy industry.

Key Words: *chia seeds, model system, gelation, dairy*

GELS

GELATION OF HIGH PRESSURE HOMOGENIZED HAZELNUT MILK WITH GLUCONO DELTA-LACTONE (GDL): RHEOLOGICAL AND GEL STRENGTH PROPERTIES

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ABSTRACT

In this study, high pressure homogenized (HPH) hazelnut milk samples were acidified with glucono delta lactone (GDL) and rheological and gel strength properties of the cold set gels were characterized. Hazelnut milks were prepared by mixing of hazelnut meal (10% (w/v)) with distilled water using a rotor-stator homogenizer, and then, samples were treated with HPH at 0, 50, 100 and 150 MPa pressures. Hazelnut milk prepared without HPH treatment was used as control. Hazelnut milks were mixed with GDL (2% w/v) on a magnetic stirrer for 1 min, and then, gelation of hazelnut milks were observed with small deformation oscillatory measurements during 150 min. After 150 min of gelation, samples were characterized in terms of steady and dynamic shear rheology and gel strength. Hazelnut milks acidified with GDL displayed shear thinning behavior due to decreasing viscosity with increasing shear rate, however HPH caused to increase of apparent viscosities of cold set hazelnut milk gels. Ostwald de-Waele model was adequately described the flow behaviors of hazelnut milk gels (R^2≥0.985), and the highest consistency index (5.934 Pa.s^n) was observed from hazelnut milk treated at 50 MPa. Cold set hazelnut milks were characterized as weak gel-like macromolecular dispersions with storage modulus (G') much greater than loss modulus (G''). The lowest gel strength (14.05 N) was observed from control samples, whereas the highest value (20.56 N) was determined from 50 MPa HPH treated hazelnut milk. Angular frequency dependence of complex modulus (G^*) was studied to measure the strength of cross-linking protein network of suspension systems by calculating a constant order of relaxation function (α) and concentration dependent stiffness parameter ($A\alpha$). Material stiffness ($A\alpha$), consistency index (K) and gel strength results of HPH treated cod set hazelnut milk gels were well correlated. This study revealed for the first time that hazelnut proteins can form good gel structures with acidification, and gel properties can be improved by HPH treatment. Due to its balanced amino acid profile and a high biological value, hazelnut milk may be an interesting raw material to study further.

Key Words: *gelation, hazelnut milk, rheology, gel strength, glucono delta-lactone*

GELS

MODULATING HYDROGEL CHARACTERISTICS OF DEACETYLATED SALEP GLUCOMANNAN BY BLENDING XANTHAN GUM

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ABSTRACT

Despite non-gelling characteristic of salep, removing acetyl groups of glucomannan with a degree of 100% provided thermo-irreversible gel formation, as reported previously. However, this thermal behavior of glucomannan can restrict its food applications. Therefore, in this research, the effect of xanthan gum (X) combination with deacetylated salep glucomannan (S) at different ratios (1:1, 1:3 and 3:1; coded as SX, 3SX, 3XS) was investigated to modulate the rheological and textural behaviors of the deacetylated salep glucomannan hydrogel. Regarding heating period of hydrogel, temperature independency of salep hydrogel changed with xanthan combinations and salep- xanthan combinations demonstrated crossover gel-sol transition temperatures between 67-72°C indicating that mixture had thermo-reversible gel characteristics. Higher salep ratio of solutions exhibited higher gelation temperatures. Deacetylated salep gel exhibited strong gel behavior but blend hydrogels had weak gel property and lower moduli values than individual salep hydrogel. Creep-recovery tests showed that xanthan addition weakened the structure of deacetylated salep hydrogel. Texture analysis showed that gel strength values of salep hydrogel decreased with xanthan addition and 3XS had higher gel strength. The results indicated that molecular association of xanthan molecules with GM chains can be used to modulate thermal and gel behavior of deacetylated salep glucomannan hydrogel.

Keywords: *deacetylation, hydrogel, thermal behavior, rheology, texture*

INTRODUCTION

Salep is made from plant tubers from the Orchidaceae family and is a good source of glucomannan (GM), which is composed of linear chains consisting of glucose and mannose connected by β-(1 → 4) glycosidic bonds. The tubers are usually grown in eastern Mediterranean countries. After boiling in water, the tubers are dried and then ground to produce salep powder. Salep has been used in different application such as a traditional beverage and a stabilizer for hard-serve ice cream, drinks and medicines [1].

The composition of salep has been reported as 56.1% glucomannan, 36.31% starch, 4.60% protein and 2.07% ash. Starch, protein and ash were considered as impurities which decreasing quality and flow behavior characteristics of used systems. Salep powder was obtained with 95% GM content and 6 fold higher viscosities than crude salep by purification studies. Another aim of obtaining purified salep was that to search its gelation properties [2]. Despite purified salep exhibited a predominantly elastic behavior ($G' > G''$), hydrogel formation was not observed. Therefore, as a chemical modification method, deacetylation process were performed to reveal gel formation potential of salep. The presence of acetyl

group of salep (2.2%) was eliminated by using NaOH at different degree. Hydrogel formation of salep (at 0.5, 0.75 and 1.0% GM concentration) was observed at 100% DD. The gel obtained with deacetylation had thermo-irreversible and high gel strength character. The gelation mechanism was attributed to the aggregation of glucomannan chains through linkages such as hydrogen bonding and hydrophobic interaction as a result of removing acetyl groups with the aid of alkali. This gelation mechanism was widely reported for konjac glucomannan which is another main GM sources and has long been used in China and Japan. The revealing gelation property of salep was important to broaden the utilization of salep in different fields of polymer application [3]. However this thermal behavior will restrict its food applications. Therefore, combination with xanthan was aimed to vary thermal and gel strength behavior of salep hydrogel, namely rheological and textural characteristics.

Xanthan gum is a polysaccharide produced by "*Xanthomonas campestris*" that is widely used in various food applications due to the rheological behaviors of water solutions. The high viscosity of aqueous xanthan gum solutions is observed as a result of high molecular weight of xanthan gum [4, 5]. It is widely used as a food additive and rheology modifier with the properties of the low cost, biodegradable, easy availability, and non-toxic [6]. Aqueous XG solution exhibits the state of an ordered and rigid double helical strand structure at low temperature. Owing to the three-dimensional network formed by associated XG chains, aqueous XG solution shows weak gel-like properties. On the other hand, it does not form actual gels at any concentration which is attributed to the weak non-covalent interactions between different XG molecular chains [7].

The expected result of this research is modification of chemical bonds and especially increasing hydrophilic interaction rate in hydrogel structure by xanthan gum combinations using its disordered coil conformation at high temperature because blend solutions were obtained at 80°C.

MATERIALS and METHODS

Materials

The native salep powders were purchased from a supplier in Kastamonu. The glucomannan of salep was purified by mixing the sample with distilled water at room temperature to extract the glucomannan, followed by centrifugation to remove the insoluble materials. The glucomannan was then precipitated with ethanol. The Mw and PDI values of purified glucomannan were determined to be 1.03 × 106 g/mol and 1.78, respectively, via high performance size-exclusion chromatography. Dried, milled and purified salep glucomannan (94.25%) was used for solution preparation [2]. Xanthan (XG) was purchased from Sigma Chemical Co. (St. Louis, MO, USA).

Preparation of the Salep Glucomannan-Xanthan Blended Solutions

Aqueous solutions of xanthan gum (XG) and salep glucomannan (SG) were prepared in distilled water and then blended at 80°C with mechanical stirring (15 min at 200 rpm) to obtain SG:XG blend solutions (3:1, 1:1 and 1:3; coded as 3SX, SX, 3XS) with a total polysaccharide concentration of 0.5 g/100 mL. In addition, at same temperature and stirring conditions, individual solutions of SG and XG hydrocolloids (coded as S, X) were prepared in distilled water (0.5 g/100 mL). The structure of xanthan in distilled

water, at low temperature, is a partially ordered broken helix, indicating the rheological behavior of a weakly structured material. At high temperatures, an ordered (helix) to disordered (coil) conformational transition occures that turns the gel-like behavior to terminal Newtonian flow [4]. Therefore, all solutions were prepared at 80°C.

Rheological Properties of Solutions and Gels

The rheological properties of solutions and gels were determined by using a rheometer (HAAKE Mars III; Thermo Scientific, Germany) that was equipped with a cone and plate configuration (diameter: 35 mm, cone angle: 2°, gap size: 0.150 mm). In rheological experiments, temperature sweep tests were conducted to all solutions while strain, frequency and temperature sweep and creep-recovery tests were performed for gelled samples. All rheological experiments were conducted three times.

Determination of the Gelation Temperature of the Solutions

The temperature sweep measurements were carried out at a constant stress and frequency of 0.1 Pa and 1 Hz, respectively. Temperature range was from 80 to 20°C with a rate of 2°C/min.

Dynamic Viscoelastic Properties of Gels

Before the frequency sweep tests, to obtain measurements in the linear viscoelastic region (LVR), stress sweep measurements were carried out in the range of 0.01–100 Pa at a frequency of 1 Hz. Frequency sweep tests were carried out for a frequency range of 0.1–100 Hz at 1 Pa. The *G′* and *G″* moduli values were plotted. These measurements were done at 4°C, after maintaining for 60 s at this temperature. Temperature sweep tests were conducted at a constant stress and frequency of 1 Pa and 1 Hz, respectively, over a temperature range of 4–90°C at a heating rate of 2°C min^{-1}.

Creep-Recovery Measurements of Gels

The creep test was recorded at constant stress amplitude (1 Pa). The stress was applied instantly and maintained at 4°C for 150 s. After removing the stress, samples were released to recover for 150 s.

Determination of the Gel Strength

A texture analysis was carried out using Texture Analyzer (TA-XT2 Stable Micro Systems Co., Ltd., Surrey, UK) to determine the gel strength of the samples. For each sample, three measurements with two replicates were performed using a cylindrical probe (5 mm diameter) attached to a 30 kg load cell. The penetration depth at the geometrical centre of the samples was 10 mm, and the penetration speed was set at 1.0 mm s^{-1}. Salep glucomannan xanthan mix solutions were stored in containers (35 mm diameter and 20 mm height) to obtain gel at +4°C for 24 h. The gel strength expressed as stress was calculated as follows:

$$\sigma = \frac{F}{\pi \times r^2} \quad (1)$$

where σ, *F* and *r* are the stress (kN/m^2), the maximum force (N) and the radius of the cylindrical probe (m), respectively.

Determination of the Gel Color

The gel samples were subjected to colour measurement using a Colorflex, EZ (Hunter associates laboratory, USA). Before use, the colorimeter was standardized using a white calibration plate. The *L**-value (lightness), *a**-value (redness/greenness) and *b**-values (yellowness/blueness) were determined to calculate the whiteness index (WI) of the salep-xanthan gels as follows [8]:

$$WI = 100 - \sqrt{(100 - L^*)^2 + (a^*)^2 + (b^*)^2} \quad (2)$$

RESULTS and DISCUSSION

Gelation Temperature of Solutions

Figure 1 shows the temperature dependency of modulus (*G'* and *G"*) during cooling ramp (80 to 20°C). The determination of gelation temperatures are categorized into two methods: (i) cross point of the moduli (*G'*=*G"*) (ii) the onset point where storage modulus started to increase sharply [9]. As seen Figure 1, xanthan solution had crossover point but solution did not produce gel following the aging period (neither at the end of the measurements nor after storage at 4°C). Xanthan has already known as non-gelling polymer and considered as pseudo-gel. On the other hand, deacetylated salep solution has no gelation temperatures but at the end of the aging period strong thermo-irreversible gel was obtained. Therefore, combinations of these gums proved in this study.

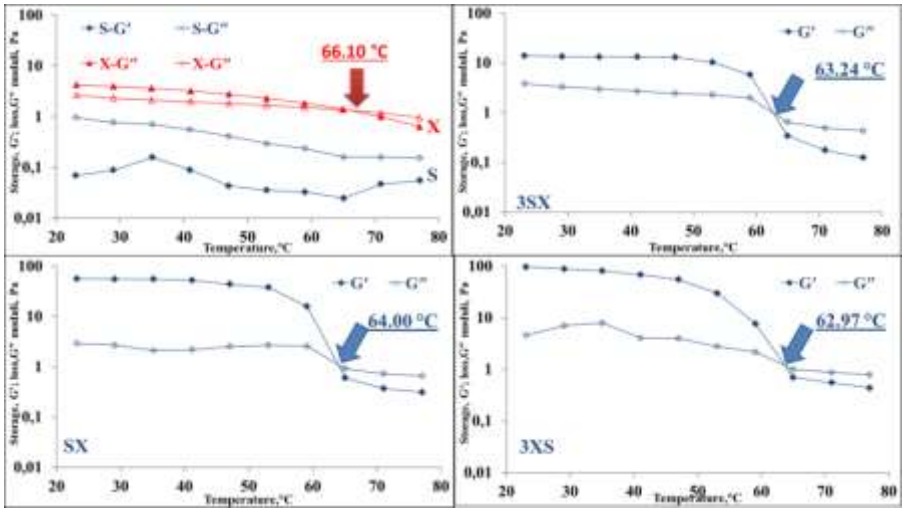

Figure 1. The temperature dependency of storage (*G'*) and loss modulus (*G"*) during cooling ramp of the aqueous solutions of xanthan (X), deacetylated salep glucomannan (S) and their blend solutions with different ratios (3XS, XS, and 3SX)

A seen in Figure 1, temperature dependency of mixture exhibited different behavior as compared with individual solution. Sharply increase in modulus was determined for mixture and all mixtures exhibited gel formation at the end of the measurements. The system can be regarded as “soft gel” when 10<*G'*<1000 Pa and *G'*>*G"* [10]. Therefore, the obtained gels were characterized as soft gel. Crossover point changed between 62-64°C for solutions. The results indicated that xanthan usage provided early gelation system and also showed the possibility of the regulation of gelation temperature by ratio change. It seems that xanthan ratio increment in system resulted in higher storage modulus values for the non-aged solution. At the end of the cooling ramp, moduli reached maximum values (fall in the soft

gel range) and remained as stable with no decreasing, due to the lacking of syneresis behavior of blend gels, consisted with the results of water holding capacity of gel. The remarkable decrease of *G'* values was reported for carrageenan gels due to syneresis [11].

Dynamic Viscoelastic Properties of Gels

This experiment was performed to samples which aged at 4°C for 24 h. It is known that in the gel systems, G' is greater than G'' at the applied frequency range. Results of frequency sweep test showed that G' modulus was greater than G'' modulus at all frequency ranges (Figure 2). As expected, thermoirreversible gel, S had higher modulus values and higher departure between modulus indicating higher elastic behavior and lower tan δ values of sample S and also slightly frequency dependency at high frequency about 100 Hz. The addition of xanthan gum lowered the modulus, departures between modulus (indicating lower elastic modulus) of salep hydrogel. As presented in figure, for the xanthan added system, the rheological parameters (G' and G'') showed less frequency dependence at low frequency and higher dependence at higher frequency, such behaviour could indicate the weakening of the gel structure as a result of a higher contribution of the viscous component. It is significant and occurred at lower frequency for XS samples than other blend systems. 3SX gel system could be considered as the weakest gel structure due to the lowest modulus values and higher frequency dependency. The results also showed that the presence of xanthan in gel system with high ratio resulted in strengthened gel matrix while lower ratio of salep is weakening.

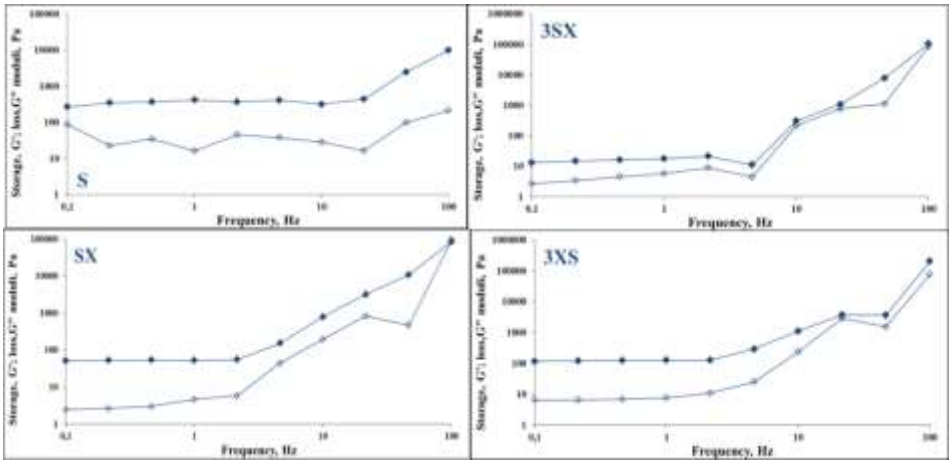

Figure 2. The frequency dependency of storage (G') and loss modulus (G'') of deacetylated salep glucomannan gel (S) and their blend gels with xanthan (X) at different ratios (3XS, XS, and 3SX)

To determine the thermal transition change with xanthan addition to salep glucomannan gel, temperature sweep tests were performed on equilibrated gels. Time-independent behavior and no crossover point meanly thermoirreversible character of deacetylated salep gel changed with xanthan combinations (Figure 3). Regarding blend gel systems, both modulus of gel samples exhibited significant decrease after about 60°C as a result of changing interactions in gel structure and crossover points were observed for xanthan-salep gel systems indicating thermal behavior changed to thermoreversible behavior. Addition of xanthan with lower ratio had higher transition temperature but lower modulus values on the other hand high xanthan including gel samples had higher modulus values and lower

crossover point. The lower transition point was attributed to reduced entanglement or weaker interactions in the structure, thus making the viscoelastic behaviors more sensitive to temperature.

The results showed that the presence of xanthan increased hydrophilic interactions ratios in the other words hydrophobic interactions were lowered in gel structure therefore xanthan could be evaluated as manipulating agent to modulate temperature transition of deacetylated salep gel.

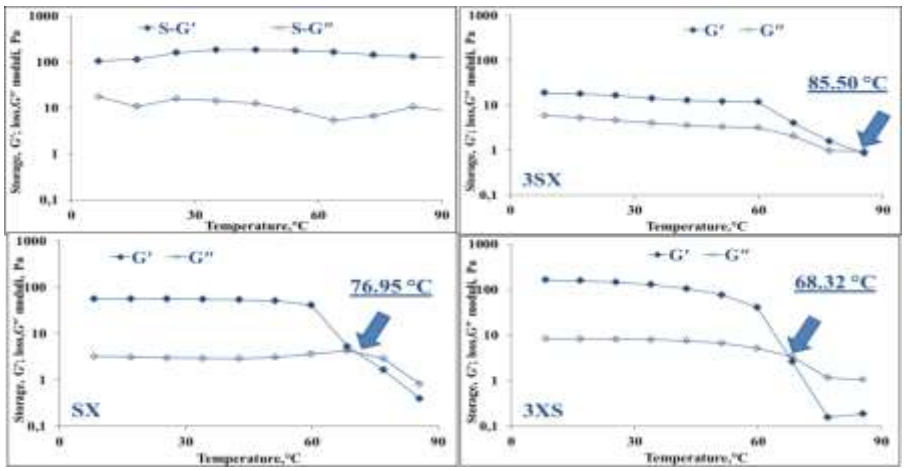

Figure 3. The temperature dependency of storage (*G'*) and loss modulus (*G"*) during heating ramp of deacetylated salep glucomannan gel (S) and their blend gels with xanthan (X) at different ratios (3XS, XS, and 3SX)

Creep-Recovery Measurements of Gels

The creep-recovery curves of the salep with different ratios of xanthan gums are shown in Figure 4. The results showed that all creep-recovery curves of gel samples exhibited viscoelastic behavior with both viscous fluid and elastic components. The creep and recovery properties of a viscoelastic system characterized with the reorientation of bonds and alignment of microstructures [12]. In this test, the slow deformation of samples under constant stress occurred, which allows measurement of the small molecular motion in a more sensitive way than through oscillatory testing (creep). The deformation value is obtained after removal of the stress (recovery), which allows the material to return to its original state [13]. A higher value of compliance represents a weaker structure and a lower value shows a stronger structure [14, 15]. It can be found that the strains subjected to a constant stress of deacetylated salep gel significantly increase with the xanthan gum addition and increase in xanthan ratio decrease strain in the creeping stage. It means that the salep gel with xanthan gum addition exhibits lower resistance to the stress and produces a weaker microstructure network as compared with deacetylated salep gel. This result was expected to widening salep gel applications and xanthan could be used as a modulating agent. The results were consistent with Burger's model parameters and the frequency sweep test.

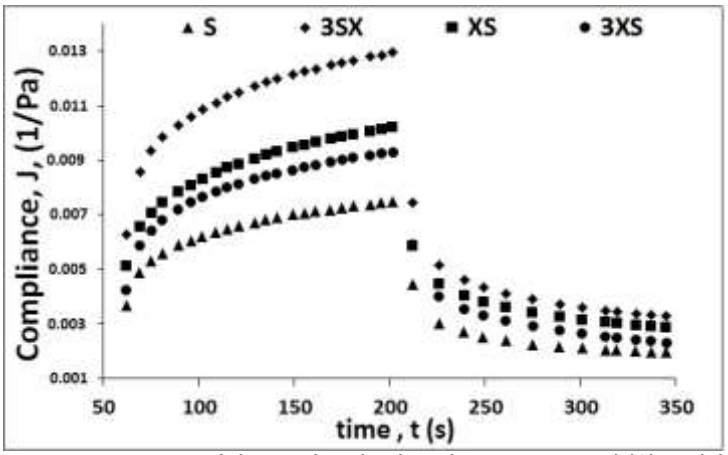

Figure 4. The creep-recovery curves of deacetylated salep glucomannan gel (S) and their blend gels with xanthan (X) at different ratios (3XS, XS, and 3SX)

Gel Color and Gel Strength

The whiteness index (WI) and strength of the gel obtained from deacetylated salep and xanthan with different ratios were presented in Figure 5. The WI values decreased with the presence of xanthan. The color value was mostly associated with the bond formation between deacetylated glucomannan. Salep gel without xanthan had the formation of compact structures, reduced water content and it can scatter light so WI values are high [16]. However xanthan addition changed the bonds in structure increased hydrophilic behavior and water, decreased cristallinity which resulted in decrease of scattering light. There were no significantly differences between blend gels for WI values.

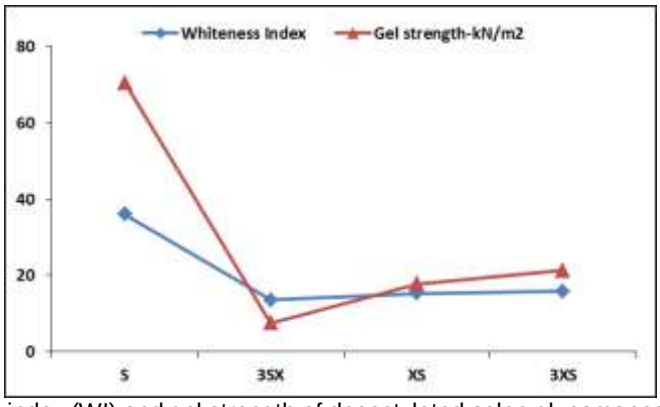

Figure 5. The whiteness index (WI) and gel strength of deacetylated salep glucomannan gel (S) and their blend gels with xanthan (X) at different ratios (3XS, XS, and 3SX)

The gel strength value is one of the most important properties of gel structure to determine its specific applications. In addition to the thermo-irreversible character, deacetylated salep gel had high gel strength values so we also aimed to decrease and modulate with xanthan usage. As expected and consistent with rheological experiments, the presence of low xanthan ratio significantly reduced gel strength values and increasing xanthan ratio provided improvement in the firmness of gel. Similar trend was observed in WI and gel strength because the entanglement ratio and interaction between glucomannan and xanthan correlated with light scattering ability which is high for firmer system [3, 16].

The physical appearance of gel samples were presented at Figure 6. Gel structure of deacetylated salep gel was changed by the addition of xanthan. Low xanthan addition caused to lose firmer structure of thermo-irreversible gel but increasing xanthan ratio reformed the gel structure.

Figure 6. The physical appearance of deacetylated salep glucomannan gel [3] (S) and their blend gels with xanthan (X) at different ratios (3XS, XS, and 3SX)

CONCLUSION

As a result, thermos-irreversible and high gel strength behavior of salep gel could be modulated with xanthan combination. Gelation time was diminished with xanthan, temperature and frequency dependency of gel salep gel increased. Gel-sol transition was observed between 68-85°C and gel system gained thermally reversible character with xanthan. Consistent result about the structural change was confirmed by creep-recover measurement. Gel strength values reduced with xanthan. All results also showed that in blend system, high xanthan ratio provided higher viscoelastic and textural characteristics and changing its ratio could be manipulated to obtain desired food products. The results were important to broaden the utilization of deacetylated salep gel in different fields of food and polymer applications.

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EMULSIONS

EFFECTS OF MICROPARTICULATED PROTEIN ON STABILITY AND RHEOLOGICAL PROPERTIES OF REDUCED-FAT WHITE-BRINED CHEESE EMULSION

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ABSTRACT

Cheese emulsion is prepared before spray drying process in cheese powder production. The fat reduction in the emulsion formulation causes some undesirable changes in flowability and viscosity. Microparticulated protein (MP) is used to mimic the functions of fat in dairy products. In this study, the ability of MP to imitate the fat in in reduced-fat cheese emulsion was investigated. Reduced-fat cheese emulsions (RF) having different MP ratios (0-20% based on cheese DM of emulsion) and different dry-matter contents (DM) (15, 20, 25% excluding emulsifying salt), and full-fat emulsion (FF) (25% DM) for comparison were produced. Rheological analyses were performed using a rotational cylinder viscometer by increasing shear rates from 1 to 1000 s^{-1}. Stability, composition (moisture, fat, protein, ash), pH and titratable acidity of emulsions were also analyzed.

No phase separation after centrifugation and during holding time was observed for RF with 20 and 25% DM whereas RF with 15% DM was not stable at any stages. The addition of MP did not have any considerable effects on phase separation in RF with 15% DM. Average shear stress versus shear rate were used to analyze flow properties by fitting to the Power Law model. The fat reduction caused significant increases in apparent viscosity values of the samples. Although the reduction in DM from 25% to 20% significantly decreased the apparent viscosity value of RF, it was still higher (0.405 Pas) compared to that of FF with 25% DM (0.138 Pa.s). Even the lowest level of MP was successful to decrease the stress values and to increase the flowability of RF emulsions. Further increases in MP amount led to a decrease in the values of consistency index (*K*) and an increase in the values of flow behavior index (*n*). The addition of 10-20% MP in RF formulation resulted in similar rheological characteristics to those of FF. In conclusion, MP can be used for obtaining suitable rheological characteristics of RF to feed easily to atomizer during spray-dried cheese powder production.

Key words: *spray drying, cheese emulsion, emulsion rheology, microparticulated protein*

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EMULSIONS

EMULSIFYING PROPERTIES OF COMMONLY USED WALL MATERIALS AND SELECT PLANT PROTEINS FOR STABILIZATION OF BLACK PEPPER SEED OIL EMULSIONS

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ABSTRACT

Black pepper (*Piper nigrum* L.) seed oil is widely used in food, cosmetic, and pharmaceutical industries not only because of its aromatic properties but also its antioxidant and antimicrobial activities. Encapsulation of essential oils offers advantages such as increased utilization, longer shelf life, easier handling and transport. The first and one of the most important steps of encapsulation of essential oils is emulsification. The aim of this study was to investigate the physicochemical and emulsifying properties of commonly used wall materials (maltodextrin, gum acacia, modified starches HiCap and M-Cap) and select plant proteins (soy, pea, hazelnut and pistachio proteins) in stabilization of black pepper seed oil emulsions.

Moisture content was measured gravimetrically whereas water activity (a_w) was determined using a vapor sorption analyzer. Glass transition temperature (*Tg*) of the samples was determined using a differential scanning calorimeter. Viscosity of 10% (w/w) solutions were measured at 40°C and 100 s^{-1} shear rate. Surface tension and interfacial tension of 1% (w/w) solutions against black pepper seed oil were measured using a tensiometer. Emulsifying activity index (EAI) of samples was determined using a spectrophotometric method.Moisture content of the wall materials studied ranged between 5.3-11.5% whereas their a_w changed between 0.22-0.46. Modified starch HiCap had the lowest *Tg* (42°C) followed by pistachio protein concentrate (45°C) whereas maltodextrin and pea protein isolate had the highest *Tg* (~99°C). Viscosity of samples ranged between 8-54 mPa.s; proteins showing significantly higher viscosity values compared to maltodextrin and modified starches. Surface tension changed between 42-60 mN/m with modified starches and pea protein isolate showing the lowest surface tension. On the other hand, interfacial tension ranged between 10-14 mN/m; plant proteins exhibiting lower interfacial tension. EAI of the samples changed between 3-25 m^2/g. Pea protein isolate and modified starch M-Cap had the highest EAI (~25 m^2/g).

Among the samples studied, pea protein isolate had the highest Tg and was able to decrease the surface and interfacial tension effectively and hence had the highest EAI. Our results have shown that pea protein isolate can serve as an effective emulsifier and wall material in encapsulation of black pepper seed oil.

Key words: *emulsion stability, plant proteins, black pepper seed oil*

QUALITY CRITERIA

RHEOLOGICAL AND THERMAL PROPERTIES OF GLUTEN-FREE TEMPURA BATTER SYSTEMS FORMULATED WITH QUINOA AND CORN FLOUR

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ABSTRACT

Batter coatings are used for improving fried food quality by reducing fat uptake, preventing moisture loss and enhancing appearance, flavor, texture, weight and volume of final product. The objectives of this study are to evaluate the effects of quinoa and corn flour incorporation on rheological and thermal properties of tempura batters. Quinoa and corn flour were mixed at four levels (w/w, % of flour) namely 40:45; 45:40; 50:35 and 55:30, respectively. The rheological characteristics of batters were evaluated using DHR3 rheometer with parallel-plate geometry at 15°C. The batters exhibited shear-thinning behavior. Storage modulus (G') was higher than loss modulus (G'') and both values increased with increasing frequency for all samples. Shear stress (Pa) versus shear rate (s^{-1}) data provided a good fit to Power-law (R^2>0.98) and Herschel-Bulkley model (R^2>0.97). The consistency index determined with Power-law varied between 176.00-213.10, while for Herschel-Bulkley model it varied between 166.70-198.90 Pa.s^n. Increasing rate of quinoa flour resulted in higher consistency index. Thermal properties of quinoa and corn flour were analyzed with DSC. Gelatinization onset and peak temperatures of quinoa and corn flours were found as 57.45°C-64.35°C and 64.69°C-70.40°C, respectively, and the gelatinization enthalpies were determined as 1.513 and 1.077 J/g.

Key Words: *rheology, tempura batter, gluten-free, mathematical modelling*

INTRODUCTION

Batters for food coating applications are grouped into two categories as; interface/adhesion batter and puff/tempura batter [1]. The main difference between these categories is that the tempura batter involves leavening agent. Low protein and wheat flour containing batters are recognized as tempura batter in Japanese cuisine and they are generally used for coating of deep-fat fried vegetable and seafood [2]. However, ingredients may include rice, corn, soy and barley flours, various types of starches, gums, dextrins and etc. [1, 3, 4]. Depending on the ingredients used in formulation, tempura batters have a rather complex structure [1], and pre-frying step is important on final product quality. Gluten in wheat flour improves tempura batter structure with gas retention during leavening due to cohesive network formation [1, 5]. On the other hand, wheat flour consumption is not recommended in gluten-free diets, so the food formulations are modified by using gluten-free ingredients. In gluten-free batter formulations, rice flour, tapioca flour and potato starch are utilized for creating similar structure with wheat flour batters. However, current literature does not include employing quinoa and corn flours in tempura batter formulations.

In this study, rheological and thermal properties of gluten-free tempura batters composed of quinoa and corn flour mixture were examined.

MATERIALS and METHODS

Materials

Whole white quinoa seeds (Origin: Peru, Duru Lival; Turkey) and corn flour were purchased from Degirmen Tic. (Izmir, Turkey), xanthan gum (Sigma-Aldrich, USA), maltodextrin DE 5-7 (Hasal Tarim Urunleri A.S., Turkey), dextrose (Riedel-de Haën, Germany), baking powder (Dr Oetker, Turkey) and salt were purchased from a local market. Whole quinoa seeds were ground in a lab-scale hammer mill (Armfield, UK) and both quinoa and corn flours were sieved through 500 and 710 µm screens, respectively.

Analysis of Flour Samples

Water absorption capacity (WAC) and moisture contents of flour samples were determined according to AACC method no 56-11 [6] and ICC 110/1, respectively [7]. Each analysis was performed with four replicates and average values are given in Table 1. WAC and moisture content of quinoa and corn flour were determined as 118±1.64% and 127±1.42%; 8.34±0.32% and 8.59±0.28%, respectively.

Batter Preparation

Gluten-free tempura batter formulations given in Table 1 are adapted from [1], but formulation was modified as gluten-free. The batters were prepared with cold water (4°C) at 1:1.3 ratio as it was recommended by literature [2, 4, 5]. Firstly, water and all dry ingredients except gum were mixed thoroughly for 1 min at medium speed and after adding xanthan gum, batter was mixed for 30 s at high-speed in Philips HR1674 mixer (Philips, Argentina).

Table 1. Tempura batter formulations

	Samples			
Ingredients	40Q:45C	45Q:40C	50Q:35C	55Q:30C
Quinoa flour (g)	40	45	50	55
Corn flour (g)	45	40	35	30
Maltodextrin (g)	10	10	10	10
Dextrose (g)	2	2	2	2
Salt (g)	2	2	2	2
Baking powder (g)	1	1	1	1
Xanthan gum (g)	1	1	1	1
Water (ml)	130	130	130	130

Rheological Properties of Batters

All rheological measurements were conducted at constant temperature (15°C) using a DHR3 rheometer (TA Instruments, USA) with a parallel plate geometry (OD: 40 mm). For linear viscoelastic region and difference between the batters, amplitude sweep analyses were carried out between 0.1-100% strain and frequency sweep tests were performed at 1% strain between 0.01-10 Hz. Because all of samples showed linear region between 0.1-10%. To determine flow behavior of batters; shear stress was recorded as a function of shear rate between 0.01-100 s^{-1}. Temperature dependency of batters was

determined by monitoring storage (G') and loss (G'') modulus between 15-80°C at 5°C/min rate and under constant frequency of 1 *Hz*. The rheological experiments were performed in triplicate.

Shear stress (Pa) and shear rate (s^{-1}) values of batters were fitted to Power-law (Eq. 1) and Herschel-Bulkley (Eq. 2) rheological models given in below equations.

$$\sigma = K(\gamma)^n \quad (1)$$

$$\sigma = \sigma_0 + K(\gamma)^n \quad (2)$$

Here σ refers to shear stress (Pa), γ is shear rate (s^{-1}), K is consistency index ($Pa.s^n$), n is power-law index and σ_0 refers to the yield stress (Pa) values. Matlab software Vers. 8.1.0.604 (Mathworks Inc., USA) with curve-fitting toolbox were used to evaluate the rheological models.

Thermal Analysis

Thermal analysis of quinoa and corn flours were performed with a differential scanning calorimeter (Q2000, TA Instruments, USA). An empty pan was used as reference and nitrogen gas (99% purity) with 50 ml/min used as purge gas. 3 mg sample was weighed into pan and distilled water was added with dry sample to water ratio of 1:3. All the samples were scanned from 15-90°C at 10°C/min scan rate. Onset temperature (T_0), peak temperature (T_p) and enthalpy of gelatinization (ΔH_g, J/g) were determined.

RESULTS and DISCUSSION

Water absorption capacity of tempura flour mixtures plays an important role on viscosity of batter and further coating uniformity of food samples [1, 2, 8, 9]. The water content in tempura mixtures was used between 1:1.1 and 1:1.3 dry mixture to water ratio for wheat, corn and rice flour based tempura batters in literature [3, 4, 10]. WAC of quinoa flour was consistent with literature [11], and it was significantly lower than that of corn flour. Although WAC of corn flour was higher than that of quinoa flour, there was no clear tendency depending on the viscosity with increasing corn flour addition (Figure 1.). In literature, increasing level of quinoa flour with high WAC resulted in higher viscosity values [11]. Conversely, at higher shear rates (>70 s^{-1}), shear stress of batter formulations were overlapping on each other. This may be due to the level of corn and quinoa flours was not quite different in overall formulation. Also, particle size of corn flour was rather higher than that of quinoa flour, and hydration of corn particles might be delayed which in turn resulted in similar viscosities [4]. As it was given in Table 2, the tempura batters showed a shear-thinning behavior with n values being lower than 1. Besides, experimental data fitted well to Power-law and Herschel-Bulkley model with a good correlation values (R^2>0.97). However, yield stress values of Herschel-Bulkley model was so small that the experimental values were represented better with Power-law model.

Storage and loss modulus values of batters increased with respect to increasing temperatures (Fig. 1B and 1C) and the tempura batters had a solid-like behavior. The temperature ramp curves can be divided

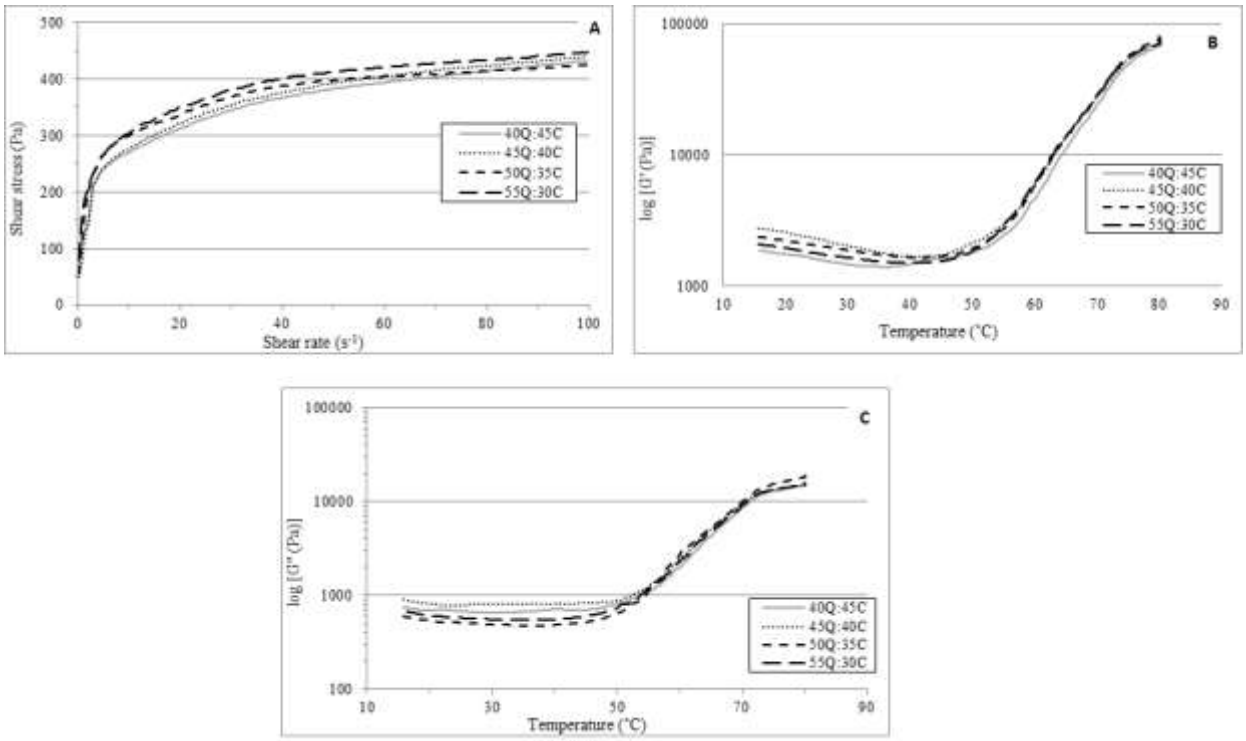

Figure 1. A: Flow curves, B: storage (G´) and C: loss modulus (G´´) of batters

into three sections such as; T<45°C, G'values decreased while G''almost stayed constant which was possibly related with reduction in viscosity of liquids [12]. Between 50-65°C both G' and G''increased with an increasing trend, while around 65°C both were increased with a decreasing trend. The sudden change in trend of tempura batters are possibly related with starch gelatinization [4], and these findings were consistent with DSC curves as well.

Table 2. Results of fitted rheological models

	Power-law				Herschel-Bulkley				
Samples	*K* (Pa.s^n)	*n*	R^2	RMSE	*K* (Pa.s^n)	σ_0 (Pa)	*n*	R^2	RMSE
40Q:45C	176.00	0.20	0.9973	3.353	166.70	0.01	0.21	0.9940	5.030
45Q:40C	177.60	0.20	0.9958	4.522	167.90	0.00	0.20	0.9926	6.039
50Q:35C	213.00	0.15	0.9855	6.754	198.90	0.01	0.17	0.9800	8.731
55Q:30C	213.10	0.17	0.9870	7.290	198.80	0.00	0.19	0.9793	9.228

Legumes and grains are major sources of starch [13], and during heating, degeneration of starch crystalline structure occurs and affects batter viscosity. Therefore these parameters alter coating features and quality of final product [4]. DSC endotherms are given in Figure 2. Except gelatinization enthalpy, onset and gelatinization temperatures of quinoa (T_0 = 57.45°C, T_p = 64.35°C, ΔH_g = 1.513 J/g) were lower than corn (T_0 = 64.69°C, T_p = 70.40°C, ΔH_g = 1.077 J/g) and the thermal properties are in agreement with literature [13, 14, 15, 16].

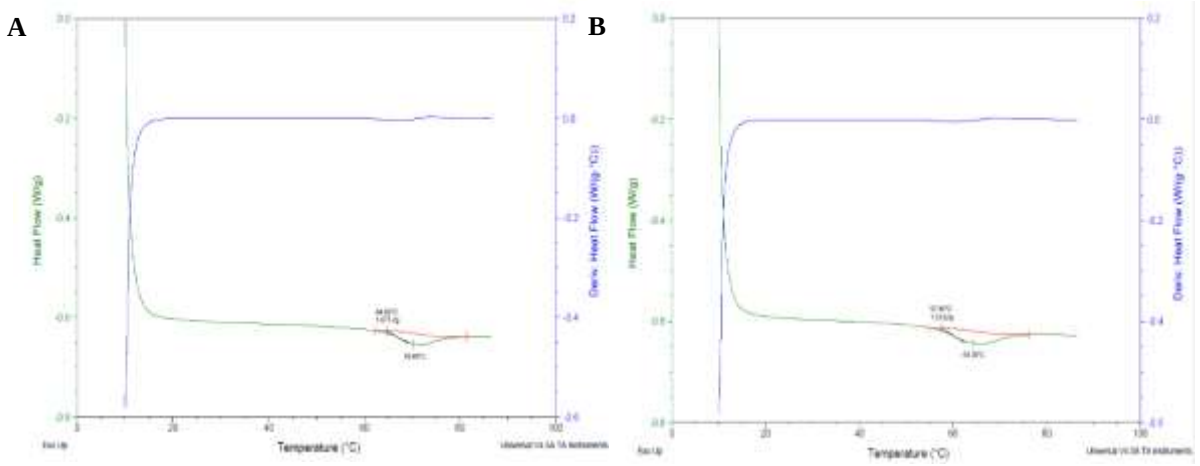

Figure 2. Heat flow curves of A: corn flour, and B: quinoa flour

CONCLUSION

Effect of increasing amount of quinoa flour in gluten-free tempura batter formulations were evaluated according to the rheological and thermal properties. Increasing quinoa flour ratio in batter formulations resulted in higher *K* values for both rheological models, except 50Q:35C formulation for Herschel-Bulkley model. All batters show shear-thinning and solid-like behavior. Quinoa flour had lower T_0 and T_p, but higher enthalpy value compared to corn flour.

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FOOD GROUPS: DOUGH

THE EFFECT OF LACTIC ACID BACTERIA CULTURES IN DIFFERENT SOURDOUGH ON DOUGH AND BREAD CHARACTERISTICS

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ABSTRACT

In this study, Lactobacillus spp. isolated from five different sourdough samples (A, B, C, D1, D2) obtained from local furnaces in Konya and also four breads (A, B, C, D) produced from these sourdough was supplied for analyses. Total titratable acidity, pH, moisture content, water activity, colour and lactic acid bacteria (LAB) counts were determined in sourdough. Also LAB colonies with different appearances were isolated to form mixed stock culture. The turbidity values at 600 nm were measured, after purification again by culturing several times. At the next culturing step, the separately replicated colonies were brought together to increase in numbers. It is aimed to simulate the natural environments by considering synergist and antagonist effects of microorganisms. A stock culture consisting of lactic acid bacteria specific to each sourdough was composed for use in subsequent studies. The texture characteristics by TPA analysis and the colour values were determined in the sourdough breads. In this study, information about the diversity of different sourdoughs and breads was obtained and the effect of the microflora of the various sourdoughs was partially observed on the end products.

Key Words: *sourdough, sourdough bread, Lactobacillus spp., subculture*

INTRODUCTION

Lactic acid bacteria are playing an important role in food technology due to their wide availability in nature, causing spoilage in various foods and maturation of some foods during the production [1]. Acidification and enzymatic activities that occur during the development of LAB have an important effect on the aroma, texture and protective qualities of various fermented foods. 6 non-pathogenic LAB strains are used in industrial applications. These include: *Lactobacillus* (milk, meat, vegetables, cereal), *Lactococcus* (milk), *Leuconostoc* (vegetable, milk), *Pediococcus* (vegetable, meat), *Oenococcus oeni* (wine) and *Streptococcus thermophilus* (milk) [2].

Some laboratories are preparing special cultures for various cheeses, butter, yoghurt and other fermented dairy products. The microorganisms involved in these cultures could be different in every pure culture. They may contain only one type of microorganism or several types of microorganisms. These cultures could be mesophilic, thermophilic and special bacterial cultures [3].

Sourdough is a mixture of flour and water with fermented by lactic acid bacteria and yeasts. The characteristic feature of sourdough is acid, aroma components and other metabolites produced by lactic acid bacteria and yeasts [4, 5]. Sourdough has properties such as acidic taste, aroma and gas formation, resulting from the addition of water to milled grains, resulting in fermentation of the natural microbial

population from the outside [4, 6]. The quality characteristics of the sourdough, such as acidic taste, aroma and gas formation, is by means of the natural microbial population from the outside [4].

The dominant microorganisms found in the sourdough are LAB and yeast [6]. Lactic acid bacteria are responsible for dough acidification, while yeasts play an important role in dough leaven through CO_2 production [7]. Interactions between microorganisms and raw materials, components and technological parameters greatly affect sourdough performance and properties [8]. Starting from this, in this study, some physical and chemical properties of five different sourdoughs taken from different bakeries were determined and some quality characteristics of the breads produced from these doughs were revealed.

MATERIALS and METHODS

Analysis of Sourdough Samples

Sourdough samples obtained from local bakeries brought to the laboratory environment at +4°C. Total titratable acidity, pH, moisture content, water activity, colour and LAB counts were determined in sourdoughs. During the LAB counts, the colonies with different appearances were isolated and purified to compose a stock culture for use in subsequent studies.

Total Titratable Acidity

10 g of sourdough was homogenized with 90 ml of distilled water using a stirrer, then titrated with 0.1 N NaOH and the results were expressed in ml NaOH.

pH

10 g of the sample was homogenized with 90 ml of distilled water and the pH was measured directly using pH-meter (660 Type, Lengpu Co., Shanghai).

Moisture Content Analysis

The moisture content of the sourdough samples was determined by drying at 135°C for 2 hours according to AACC [9].

Water Activity

Water activity values of sourdough samples were determined by using automatic water activity device (LabTouch-aw; Novasina, Switzerland).

Colour Values

L^*, a^*, b^* and ΔE^* values of sourdough samples were measured according to Hunter colour scale, using a colorimeter (Konica Minolta, CR-400, Osaka, Japan).

Enumeration and Isolation of Lactic Acid Bacteria

25 g sourdough was homogenized with 225 ml sterile MRD (Maximum Recovery Diluent) and were diluted till 10^{-7}. Enumeration of viable cells was carried out on MRS agar. Petri dishes were taken into the vacuum packaging and the oxygen is removed. The colonies were counted after 3 days incubation at 30°C. The colonies with different morphological appearance were selected and isolated. The turbidity

values at 600 nm were determined, after the isolated colonies were purification by culturing several times with MRS broth incubation. The isolated colonies were re-combined according to the doughs from which they were obtained and cultured again in MRS broth. Cryoprotectant agents were added to the grown cultures and frozen at -80°C.

Analysis of Bread Samples

Colour values and textural properties of the breads produced in the same conditions as each sourdough were determined. In this way, the effect of microbiota in sourdoughs could be determined directly without separating from its natural environment. *L**, *a**, *b** and *ΔE** values of the bread crust and crumb were measured using the colorimeter. Textural properties of bread crumb were determined by using a Texture Analyser TA-XT-plus (Stable Micro Systems, Surrey, UK). Texture Profile Analysis (TPA) analysis performed with a 36 mm diameter cylindrical probe and compression to 40% of the initial height, at a speed of 1.70 mm/s with a 5 s waiting time between the two cycles.

RESULTS and DISCUSSION

Titration acidity was observed in the lowest B sample with 5.4 ml NaOH and the highest in 13.2 ml D2 sample. The pH values of the doughs were found in the range of 3.88-5.4. Plessas et al. [10] reported that titratable acidity and pH of a commercial sourdough was 7.5 ml NaOH and pH was 4.7, respectively. It is recommended that the degree of fermentation and acidification should be pH 3.5-4.3 to achieve the desired aroma and flavour of bread [11, 12]. The moisture content of the sourdoughs was found between 41.28% (D1) and 50.78% (B). There was a random correlation between moisture content and titratable acidity values. While the lowest water activity content (0.905) had D2, no statistically significant difference was found between the other doughs (Table 1).

Table 1. Total titratable acidity (TTA), pH, a_w, moisture content, colour and LAB counts values of different sourdough samples

Sourdough Samples	TTA	pH	a_w	Moisture Content (%)	*L**	*a**	*b**	*ΔE**	LAB Counts (log CFU/g)
A	11.4^{c}	4.29^{ab}	0.921^{b}	43.13^{b}	79.75^{c}	0.12^{a}	14.41^{a}	17.99^{a}	7.70
B	5.40^{a}	5.40^{c}	0.918^{b}	50.78^{d}	68.02^{a}	3.19^{c}	20.21^{c}	31.20^{c}	8.48
C	11.4^{c}	3.88^{a}	0.912^{ab}	41.28^{a}	81.48^{d}	0.25^{a}	20.26^{c}	20.67^{b}	6.45
D1	6.70^{b}	4.60^{b}	0.917^{b}	48.91^{c}	80.47^{cd}	0.88^{b}	14.29^{a}	17.37^{a}	7.82
D2	13.20^{d}	3.95^{a}	0.905^{a}	41.51^{a}	77.18^{b}	0.62^{b}	17.05^{b}	21.62^{b}	7.73

The lowest *L** (68.02) and the highest *a** value (3.19) belong to the B sourdough, because it is produced from brown flour. It had seen that the darkness and redness of the doughs increased with using bran in the flour. The highest colour difference was observed in B dough while the least difference was observed in dough A and D1.

The maximum number of LABs was determined in B and the lowest in C sourdough. It was observed that the numbers of LABs in the other doughs were similar (Table 1). In a study by De Angelis et al. [2009] LAB cell counts of wheat sourdough before baking was determined as 9.0. The optical density values of the selected LAB colonies in MRS broth were found to be in the range of 0.149-2.137. At the

next cultivation step, the separately replicated colonies were brought together and allowed to growth. The aim here is to simulate the natural environment by considering the synergistic and antagonistic effects of microorganisms. The highest OD_{600} values at the end of the fermentation were 2.231 and 1.925, respectively. OD_{600} values of other samples (1.601-1.687) were also found to be quite high.

No difference was observed in the *L**, *b** and *ΔE** values of breads crumbs except for B samples. Because the B sample contains brown flour, it had seen darker, yellower and more colour differentiation than the other samples. The crust colour values of the breads show quite alteration because they are produced in different materials, conditions and sizes (Table 2). In a different study, *L**, *a** and *b** values of sourdough fermented wheat germ breads crust colour were found as 54.32, 10.59 and 28.34, respectively, similar to our results [14].

Table 2. Colour values of breads produced from different sourdough samples

Sourdough Samples	Crumb				Crust			
	L*	a*	b*	ΔE*	L*	a*	b*	ΔE*
A	73.30^{b}	-0.76^{ab}	13.36^{a}	23.30^{a}	61.08^{b}	9.90^{a}	33.57^{b}	45.53^{a}
B	62.45^{a}	3.26^{c}	21.05^{b}	36.47^{b}	54.97^{ab}	12.23^{ab}	30.25^{ab}	49.10^{ab}
C	72.82^{b}	-1.12^{a}	13.77^{a}	23.79^{a}	47.66^{a}	15.77^{b}	26.61^{a}	54.94^{b}
D	75.95^{b}	-0.18^{b}	13.21^{a}	20.71^{a}	60.17^{b}	10.32^{a}	32.57^{b}	46.06^{a}

According to the results of the TPA (Table 3), the softest breads are B and D, while the hardest is A sample. It has been observed that gumminess and chewiness characteristics have changed in parallel with hardness. While the cohesiveness values of the breads were not different from each other, it was found that the highest springiness value was in C and the lowest in D bread. Rizzello et al. [2010] found that the hardness and resilience of sourdough fermented wheat germ breads were 2381 g and 0.35, respectively.

Table 3. TPA values of breads produced from different sourdough samples

Sourdough Samples	Hardness (g)	Springiness	Cohesiveness	Gumminess	Chewiness	Resilience
A	875.829^{c}	0.944^{ab}	0.786^{a}	688.491^{c}	649.877^{c}	0.442^{b}
B	199.482^{a}	0.931^{ab}	0.775^{a}	154.440^{a}	143.844^{a}	0.371^{a}
C	504.476^{b}	0.960^{b}	0.788^{a}	396.700^{b}	381.243^{b}	0.455^{b}
D	238.790^{a}	0.918^{a}	0.782^{a}	186.699^{a}	171.544^{a}	0.377^{a}

CONCLUSION

In this study, the general perspective of the sourdoughs and the breads produced from these doughs were determined. Sourdough is a product that is generally variable due to the difference of natural microbiota. This variability in sourdoughs also affects the final product and its quality. In this study, it was seen that sourdoughs varied depending on production conditions, maturation period and containing microbiota and this difference was also effective on some physical properties of breads.

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FOOD GROUPS: DOUGH

EFFECT OF STALE BREAD FLOURS ON TEXTURAL PROPERTIES OF BREAD

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ABSTRACT

The bread, which is one of the most consumed foods both in the world and in Turkey, is among the most wasted food items at the same time. In this study, breads stalled for 2 days at room temperature and 7 days at refrigerator temperature under controlled conditions were converted to flour after grinding as whole and crumb. The obtained flours were added to bread formulations at 0, 15, 30 and 45% levels to produce dough and bread. 48th hour textural properties of bread samples, which were produced by adding stale bread flour, were investigated. As a result of this research, statistically significant differences (p<0.01) were observed among the samples in terms of hardness, adhesiveness, cohesiveness, springiness and chewiness parameters of the bread with increasing level of addition of whole and crumb bread flour to the formulation, obtained by stalling both at the refrigerator and at room temperature. As stale bread flour addition level increased, the parameters of hardness, adhesiveness and chewiness increased while; parameters of springiness and cohesiveness decreased. The closest values to the control were found in the sample including 15% addition level while the increase in the level of whole and crumb stale bread flours obtained from breads stored for both 2 and 7 days negatively affected the textural properties of bread. Considering the textural and other consumption quality characteristics of bread, stale bread flour could be used in bread production at 15% addition level.

Key Words: *stale bread flour, bread, textural properties*

INTRODUCTION

According to the Turkish Food Codex Communiqué on Bread and Bread Types (2012/2); bread is a product obtained with kneading, shaping, fermenting and baking according to the technique in which wheat flour, water, salt and yeast and when necessary sugar, enzymes, malt flour as an enzyme source, vital gluten and permissible additives are added [1]. Bread is one of the most basic foodstuff containing essential nutrients such as carbohydrates, proteins, dietary fiber, vitamins and minerals and it is produced and consumed all over the world [2]. Bread is important because of its high nutritional value, its neutral flavor and aroma, and its easy and cheap production as well as being easily consumed with other foods [3, 4]. In our country, daily consumption of bread was 400 grams per person in 1993, but today this amount has decreased to 250 grams. Despite this drastic decrease in bread consumption, 44% of daily calorie needs and about 50% of daily protein needs are still provided by bread [3-5].

Staling starts as soon as after production of bread via moisture loss and starch retrogradation [6]. Changes in textures and organoleptic properties along with loss of moisture during staling cause decrease in bread quality [7]. Without microbial spoilage, degradation of textural properties with staling causes non-consuming of bread and therefore wasting of it. It is stated that the most wasted food group

in the world is the cereal products and bread from these products placed in the first place [8]. According to the research done by TMO in 2013, 2.1 billion breads are thrown every year in our country and therefore there is 1.5 billion TL economic loss. Stale breads can be used in the food industry such as mixing the composition of various foods [6]. In this study, it is aimed to determine the usage of stale bread flour in bread production and its effect on textural properties of bread.

MATERIALS AND METHODS

Materials

Stale bread flours prepared for use in bread production were obtained from breads produced under laboratory conditions and stored under controlled conditions. After 1 hour cooling step, breads were stored in polyethylene bags for 2 (48 h) days at room temperature (20°C) and 7 days (168°C) at refrigerator temperature (4°C) for staling. Afterwards, half of these stale breads' crust were separated to get crumb. In order to obtain a grindable structure from these whole breads and breads' crumb, both of them were cut into 5 mm^3 pieces and dried at 40°C until the moisture content was reduced to about 10%. Dried bread pieces were grinded for get stale bread flour and packed with polyethylene bags and kept in deep-freezing until used. Stale bread flours were used in different proportions (0, 15, 30, 45%), based on the flour weight, for producing bread again.

For bread production, ingredients mixed were: 100 g of flour, 56.6 g of water, 1.5 g of salt, 2.5 g of yeast, and different proportion of stale bread flours (0, 15, 30, and 45%, depend on the flour weight). All ingredients were mixed in a tabletop mixer (Stephan UM-5) for 2 min. The dough samples were divided into 160 g portions that were manually moulded. After 30 min. fermentation (30°C and 85% Relative Humidity) step, dough portions were remolded to provide enough oxygen for yeast fermentation. Following second fermentation (30 min, at 30°C and 85% Relative Humidity), dough portions were panned by shaping before proofing for 40 min at 30°C and 85% Relative Humidity. The shaped dough portions were baked for 25 min. at 230°C. Produced bread types were stored in polyethylene bags at room temperature (20°C) until analyses. Control bread was prepared using wheat flour without the addition of stale bread flour.

Texture Profile Analyse (TPA)

Texture profile analysis of crumb slices were evaluated by Texture Analyzer (TA-XT.plus, Stable Micro System, England) using a 50 mm diameter probe, after 48 hours of storage at 20°C. Crumb samples were prepared from center of the bread in a special slicing cabin with 2.5 cm^3 height, width and depth. Hardness, adhesiveness, cohesiveness, springiness and chewiness parameters were determined. The conditions under which the textural properties of crumb determined are given in Table 1.

Table 1. TPA conditions

Test mode	Magnitude
Pre-test Speed	2.00 mm/s
Test Speed	1.00 mm/s
Post-test Speed	1.00 mm/s
Compression Rate	%50.00
Trigger Force	10.00 g

Statistical Analysis

The data obtained from this study were subjected to analysis of variance using SPSS (SPSS for Windows Release 10.0.1, 1999) packet program. The mean of the significant values of variance were compared by Duncan's multiple-range test (p<0.01) using SPSS [9].

RESULTS and DISCUSSION

The variance analysis results of textural profile analysis values of breads produced by adding stale bread flour to different levels are given in Table 2. According to the texture profile analysis results of the bread, statistically significant differences were detected between the samples in hardness (p<0.05), springiness and chewiness (p<0.01) parameters in terms of staling duration variety. However staling duration variety did not affect the adhesiveness and cohesiveness values. While the bread part variety had a statistically significant effect on hardness, springiness and chewiness values of the bread, it did not affect the adhesiveness and cohesiveness values. In addition to this, level variety had a significant effect on the hardness, adhesiveness, cohesiveness, springiness and chewiness values in terms of statistic.

Table 2. Variance analyse results of the 48th hours TPA

Variation Sources	DF	Hardness (N)		Adhesiveness (N. s)		Cohesiveness	
		MS	F	KO	F	KO	F
Staling Duration (A)	1	3.015	4.583*	0.007	1.847	0.000	1.946
Bread Part (B)	1	53.696	81.634**	0.001	0.131	0.000	2.378
Level (C)	3	777.045	1181.350**	0.169	45.823**	0.064	439.272**
A X B	1	1.239	1.883	0.001	0.176	0.002	11.309**
A X C	3	7.220	10.976**	0.003	0.884	0.001	5.836**
B X C	3	23.053	35.048**	0.009	2.433	0.000	3.287*
A X B X C	3	4.084	6.209**	0.012	3.191*	0.000	2.148
Error	16	0.658		0.004		0.000	
		Springiness				Chewiness	
		MS		F		MS	F
Staling Duration (A)	1	0.005		24.038**		0.494	7.278**
Bread Part (B)	1	0.008		40.358**		3.737	55.060**
Level (C)	3	0.162		781.532**		26.672	392.929**
A X B	1	0.006		29.631**		0.161	2.376
A X C	3	0.002		8.237**		0.551	8.116**
B X C	3	0.012		56.720**		0.816	12.026**
A X B X C	3	0.001		6.818**		0.707	10.413**
Error	16	0.000				0.068	

(*) significant at p<0.05 level, (**) significant at p<0.01 level

As seen in Figure 1, the increase in the level of whole and crumb stale bread flours obtained from stale breads stored at both 2 and 7 days caused to increase the hardness value of the produced bread. The closest hardness value to the control group was obtained with using at 15% level of whole stale bread flour obtained from staled bread for 7 days stored. The hardness values of the breads increased about 76, 390 and 837%, with addition at 15, 30 and 45% level of stale bread flours respectively when it is compared to the control.

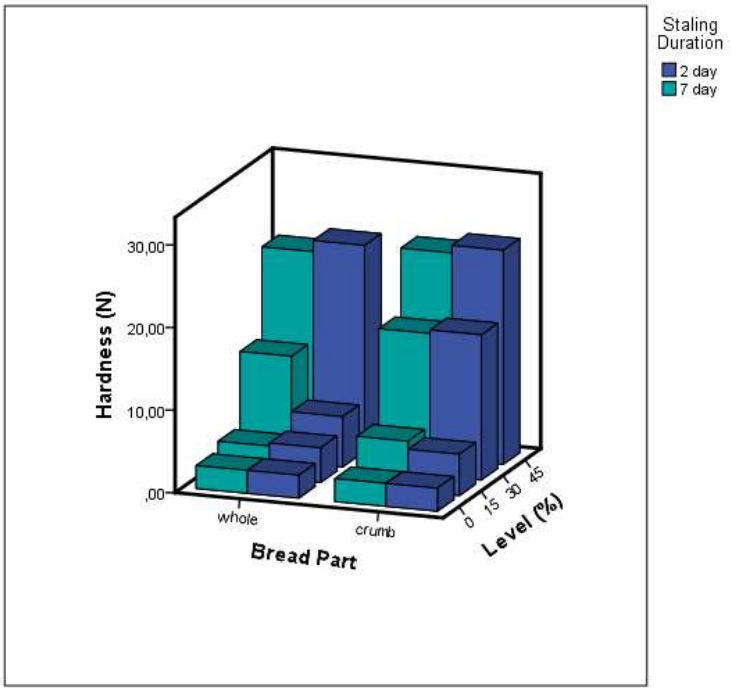

Figure 1. The crumb hardness parameter interactions of the breads

The increase in the addition level of all stale bread flours generally increased the value of crumb adhesiveness (Figure 2). 30% addition level of stale crumb flour more increased adhesiveness value than whole stale bread flour. The closest adhesiveness value to the control group was obtained with using at 15% level of whole stale bread flour obtained from staled bread for 7 days stored.

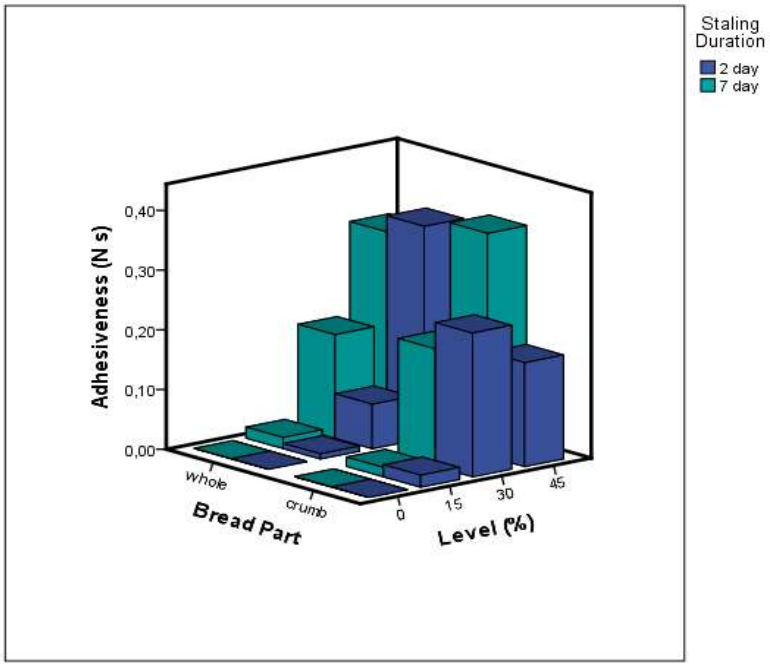

Figure 2. The crumb adhesiveness parameter interactions of the breads

The cohesiveness values of the breads regularly decreased with the increase of the level of stale bread flour (Figure 3). After the control, the highest cohesiveness value was found in the sample added at 15% level whole stale bread flour obtained from bread stored 2 days. The lowest cohesiveness value was found in sample added crumb flour at 45% level staled for 2 days.

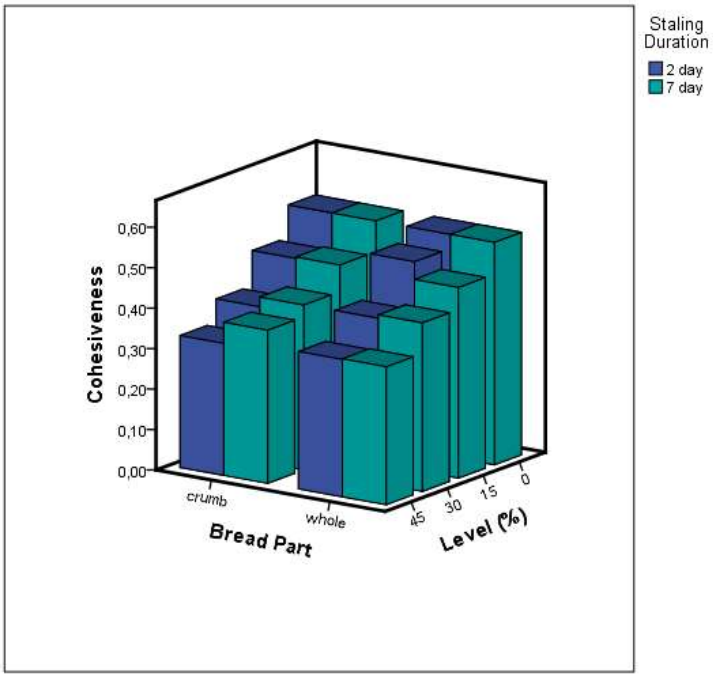

Figure 3. The crumb cohesiveness parameter interactions of the breads

As the level of stale bread flour added to the formulation increases, there is a decrease in the springiness of the breads (Fig. 4). After the control sample highest springiness value was found in breads which added whole bread flour at 15% level obtained from bread staled for 2 days. The lowest value was found in breads produced by adding at 45% whole stale bread flour obtained from stale bread stored 7 days.

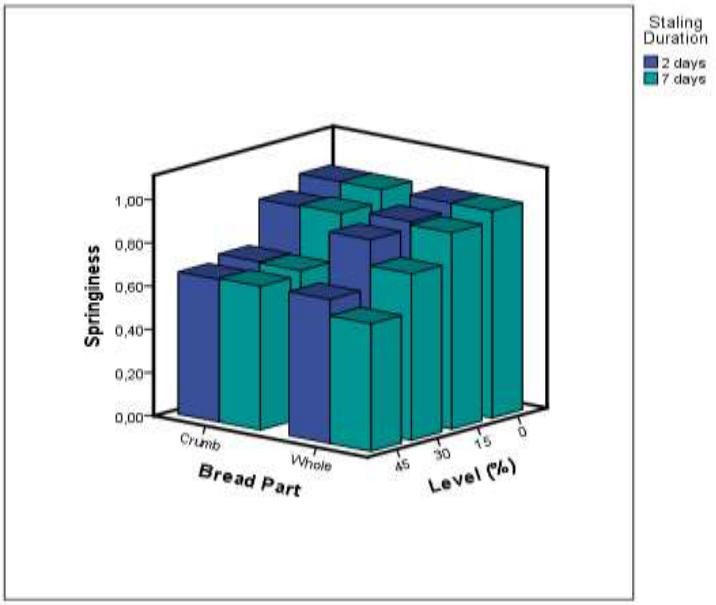

Figure 4. The crumb springiness parameter interactions of the breads

As the level of stale bread flour added to the formulation increased, the degree of chewiness of the breads increased (Figure 5). The closest value of chewiness to control samples was found in breads which added at 15% level whole bread flours staled for 7 days. The highest value of chewiness had determined in samples produced by adding at 45% level stale bread crumb flour obtained from stale bread stored for 7 days.

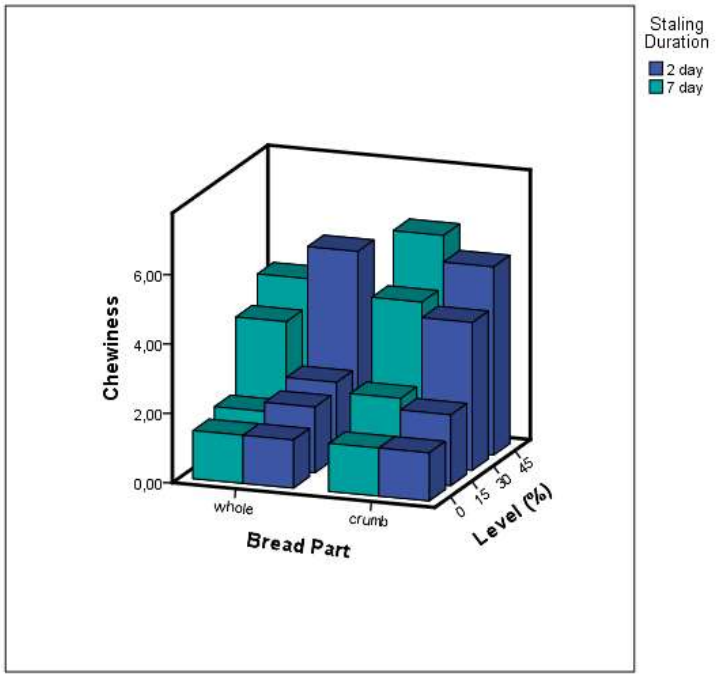

Figure 5. The crumb chewiness parameter interactions of the breads

CONCLUSION

According to the textural profile analysis results; the increase in the level of whole and crumb flours obtained from stale bread stored both in the refrigerator and at room temperature, generally increased the hardness, adhesiveness and chewiness values but decreased the springiness and cohesiveness values. It has been determined that the increase in the level of stale bread flour added to the bread formulation negatively affected the textural properties of breads and the closest value to the control was obtained at the addition level of 15%. When this research and consumer demand is taken into consideration, it is concluded that stale bread flour can be used for bread production at 15% level.

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FOOD GROUPS: DAIRY

EFFECTS OF COAGULATION TEMPERATURE, SMOKING AND STORAGE TIME ON THE TEXTURAL PROPERTIES OF ACID-HEAT COAGULATED CIRCASSIAN CHEESE

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ABSTRACT

Circassian cheese is an acid and heat coagulated cheese originating from North Caucasus. Coagulation temperature is an important parameter for these types of cheeses. In this study, both 70°C and 90°C coagulations were applied for non-smoked and smoked Circassian cheese productions. The textural effects of coagulation temperature and smoking were obtained by a texture analyzer. The results were evaluated in terms of hardness. The 90°C coagulated cheese (cheese "A") was approximately 110% harder than 70°C coagulated cheese (cheese "B") with the hardness values of 1484 g and 705 g, respectively. During 90 days of storage, all cheeses lost hardness; however, the decrease in the hardness of cheese "A" was higher than that of cheese "B". Smoking process also increased the hardness for about 35 and 45% in cheeses "A" and "B", respectively. At the end of 90 days of storage, smoked cheeses softened further than non-smoked ones. The study revealed the effects of coagulation temperature, smoking process and the storage time on the hardness of Circassian cheese.

Keywords: *Circassian cheese, texture, acid-heat coagulated cheese*

FOOD GROUPS: DAIRY

IMPACT OF VARIOUS PACKING pH VALUES ON THE TEXTURE AND SLICEABILITY OF CULTURED WHITE CHEESE

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ABSTRACT

Significant amount of Turkish White cheese is still produced in ~1 kg cheese blocks and distributed to retail stores and farmers' market in 18 kg tin can containers with brine. Portioning the cheese with the customer desired weight requires slicing process. The crumbs that occurs during cutting/portioning is undesireble for customers and causes economical losses. In this study our goals were to investigate the sliceability of white cheeses that were manufactured at various final (i.e. packing with brine) pH (5.3, 5.0, 4.7) values. For this purpose, we manufactured 4 batches of cheese at different times from high heat treated milk (78°C, 8 min) and monitored the chemical and textural properties at 1, 2, 4, and 8 wk. Cheeses that were packed at pH 4.7 were harder ($p < 0,05$) compared to cheeses that were packed at pH 5.0 and 5.3. No correlation was observed between cheese packing pH values and the size of the crumbs; however, there were a significant ($p < 0,05$) negative correlation (r = 0,63) between packing pH and crumb weight (i.e. decrease in cheese packing pH increased the crumb weight). Cheeses packed at pH 5.0 and 5.3 exhibited increasing slicing adhesiveness during storage. All cheese samples exhibited similar colloidal calcium phosphate (CCP) levels and water soluble nitrogen values during storage. This study showed that increase in the packing pH of white cheese reduced the weight of crumbs occurred during cutting. This is also the first study in the literature that the CCP content of Turkish white cheese was monitored.

Key Words: *cheese, texture, sliceability*

FOOD GROUPS: DAIRY

RHEOLOGICAL BEHAVIOR OF ICE CREAM MIXES PRODUCED WITH LYOPHILIZED PRICKLY PEAR

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ABSTRACT

Ice cream is an example of soft and complex microstructured material consisting of ice crystals, air bubbles and fat globules. It is important to apply rheology in the characterization of flow behaviors of complex structured soft solids. The study aimed to investigate the effect of different levels (1, 3 and 5%) of liyophilized prickly pear (*Opuntia ficus indica*) addition on apparent viscosity (at 1, 2, 3 and 4°C) of ice cream mixes which were measured with three replicates. As reported in many ice cream mix studies the rheological data from this study also showed that flow behavior of all mixes are pseudoplastic. The power law model well fitted to the data curve of the apparent viscosity versus the shear rate for all samples with high regression coefficients (R^2>0.99). The flow behavior index was in the range of 0.285-0.418, while the consistency coefficient varied from 24.91 to 111.75 Pa.s^n. An increase in the concentration was accompanied by an increase in the pseudoplasticity and consistency coefficient.

Key Words*: viscosity, rheology, ice cream, prickly pear*

INTRODUCTION

Prickly pear fruits are in the *Cactacea* family which includes more than 200 species which grow abundantly in the arid regions of the world. Due to high fiber, mineral and antioxidant contents of prickly pear fruits (*Opuntia spp*.) they are ideal sources for the development of nutraceuticals or functional foods [1]. Many studies have shown that the prickly pear is very rich in terms of vitamins, minerals [2], amino acids and sugars. Prickly pear plant is used as foodstuffs, for medical applications, cosmetics and for production of the cochineal [3].

Lately, some authors have emphasized the prospects of different prickly pear aerial parts as good sources of phytochemicals with proven biological activities for the food and nutraceutical industry [4-6]. This fruit is widely employed for the preparation of tea, juices, nectars, syrups, marmalades, wine, vinegar and other food products in most parts of the world, but has not been used in ice cream production.

Ice cream is often preferred by people of all ages due to the cooling effect. Because it is a milk-based dessert and the nutritional value of ice cream is high. The supplementation with fruits add value to the product by providing functional properties.

The structure of ice cream can be defined as partly frozen foam with ice crystals and air bubbles occupying majority of the space [7]. Ice cream is an excellent example of a highly complex micro-structured material which consists of continuous and dispersed phases. Continuous phase is consist of very concentrated and unfrozen sugar solution. The tiny fat globules form a dispersed phase with some of them flocculated and surrounding the air bubbles [8]. The quality of ice cream attributes, such as 'mouth-feel', are directly related to microscale features such as bubble and crystal size distributions in liquid phase, rheology and colour [9]. Due to substances such as skim milk powder, sweeteners, stabilizers, emulsifiers and flavoring agents this colloidal system has been characterized as thermodynamically unstable [10].

To the best of our knowledge, there has been no examination of the effect of lyophilized prickly pear on the properties of dairy products. The aim of this work is to determine the effect of different levels (1, 3 and 5%) of liyophilized prickly pear (*Opuntia ficus indica*) addition on the apparent viscosity (at 1, 2, 3 and 4°C) of ice cream mixes.

MATERIALS and METHODS

Prickly pear fruits were collected from Büyükeceli/ Mersin, Turkey in June, 2016. Spiny crust and seeds of fruit are removed and the remaining portion was pureed with the aid of a blender. The pulps were frozen at -20°C and lyophilized in lyophilizator at -50°C (Christ, Alpha 1-2 LDplus). Sugar, salep and emulsifier (mono- and di-glycerides) were obtained from local market in Erzurum. Skim milk powder was supplied by Pınar Dairy Products Co. (İzmir, Turkey). The cream and cows' milk were obtained from the Dairy Factory of Agriculture Faculty, Atatürk University (Erzurum, Turkey).

Ice cream mixes were produced in the laboratory of Food Engineering Department, Atatürk University (Erzurum, Turkey). The mix samples were prepared at four different compositions of 0% (control), 1%, 3%, 5% lyophilized fruit, respectively. The fat content of milk was adjusted to 6% and after this stage 18% sugar, 0.7% stabilizer (salep), 4.8% skim milk powder and 0.2% emulsifier (mono- and di-glycerides) were added to all mixes. The mixes were stirred consistently and pasteurized at 85°C for 25 s.

The apparent viscosities of the ice cream mixes were measured after 24 h aging at 4°C using a digital Brookfield DV-II Viscometer, Model RVT (Brookfield Engineering Laboratories, Stoughton, MA, USA) with equipped spindle LV-2. Apparent viscosity of each sample was measured at rotation speeds of 1, 5, 10, 20, 50 and 100 rpm for obtaining the correct measurements which were taken at 30 seconds intervals. The measurements were performed in triplicate for each sample. The viscometer consists of a temperature controlled system to control the experimental temperatures of 1, 2, 3, 4 and 5°C for three concentrations of 1, 3 and 5%.

Generally, the ice cream mixes behave as a shear thinning fluids. Therefore, the shear thinning behavior can be fitted to well by the Power Law model [11]. The data were fitted to the Power Law model to describe the flow behavior of the samples, and flow behavior index (n) and consistency coefficient (K) values were obtained from the Power Law model for each ice cream samples:

$$\mu = K\gamma^{n-1}$$

Where μ is the apparent viscosity (mPa.s), K is the consistency index (Pa.s^n), γ is the shear rate (s^{-1}) and n (dimensionless) is the flow behavior index.

RESULTS and DISCUSSION

The rheological characteristics of most ice cream mixes have been described as a pseudoplastic [12-14]. The rheological data from this study gave similar results in that all flow behavior indices (n values) were less than 1 (Table 1), which is characteristics of shear thinning behavior.

Table 1. Rheological parameters of Power law equation of ice cream mixes at various concentrations and temperatures.

Conc. (%)	Temp. (°C)	Consistency coefficient, K (Pa.s^n)	Flow behavior index, n	R^2
0	1	84.88	0.294	0.999
	2	55.94	0.332	0.997
	3	39.62	0.348	0.993
	4	31.57	0.389	0.996
	5	24.91	0.411	0.995
1	1	96.66	0.285	0.998
	2	61.39	0.323	0.996
	3	44.62	0.343	0.995
	4	35.03	0.379	0.994
	5	28.28	0.405	0.995
3	1	107.15	0.302	0.996
	2	73.79	0.316	0.999
	3	57.81	0.319	0.997
	4	37.79	0.402	0.995
	5	32.27	0.405	0.991
5	1	111.75	0.307	0.992
	2	84.37	0.311	0.995
	3	68.32	0.318	0.993
	4	53.42	0.330	0.991
	5	34.72	0.418	0.992

The power law model well fitted the data curve of the apparent viscosity versus the shear rate for all samples with high regression coefficients (R^2>0.99). The flow behavior index was in the range of 0.285-0.418, while the consistency coefficient varied from 24.91 to 111.75 Pa.s^n. All mixes showed a pseudoplastic behavior. The flow behavior index (n) values are an indication of the departure from Newtonian behavior in the pseudoplastic fluids. An increase in the concentration was accompanied by an increase in the pseudoplasticity and consistency coefficient. In the all ice cream mixes, consistency coefficients were positively correlated with the apparent viscosity. The similar results were also found in the other studies [12, 15].

The effect of pear cactus (*Opuntia ficus indica*) concentration on the apparent viscosity of the ice cream mixes at all temperatures is shown in Figure 1.

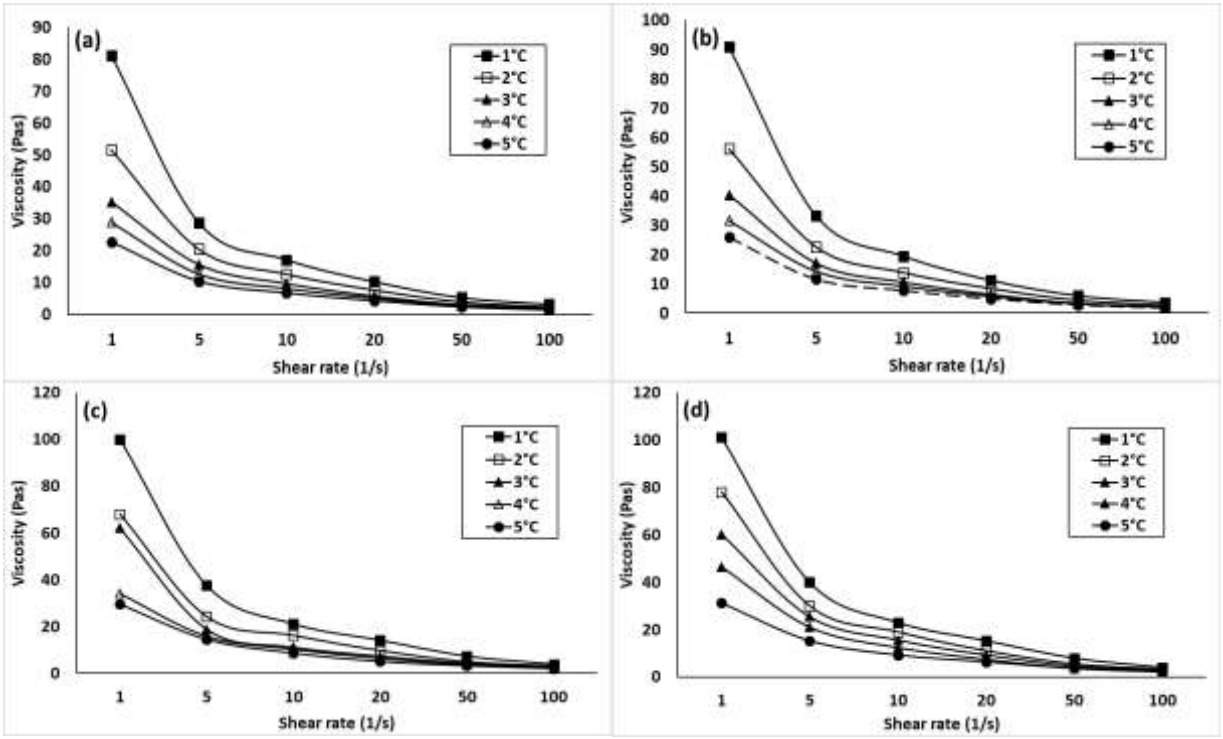

Figure 1. The relationship between viscosity and shear rate of ice cream mixes at various temperatures, 1°C (■), 2°C (□), 3°C (▲), 4°C (△) and 5°C (●)for fruit concentration at (a) 0%, (b) 1%, (c) 3% and (d) 5%.

As shown in Figure 1, the apparent viscosity tends to increase with the rise of fruit content from 0 to 5% for all shear rates as expected. On the other hand, the ice cream mixes behave as a shear thinning fluids which means that their viscosity decreases as the rate of deformation increases. The reducing in the viscosity with shear rate can be related to the increased alignment of the constituent molecules [16] and partly due to the aggregation of fat globules which decrease in size during shearing [17].

CONCLUSION

In summary, this analytical work allowed the characterization of the rheological behavior of three different levels of liyophilized prickly pear (*Opuntia ficus indica*) added ice cream samples. The findings of this study showed that in the all ice cream mixes, consistency coefficients were positively correlated with the apparent viscosity. On the other hand, the ice cream mixes behave as a shear thinning fluids which means that their viscosity decreases as the rate of deformation increases.

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FOOD GROUPS: POULTRY

TEXTURAL PROPERTIES OF OPTIMIZED CHICKEN ROLL PRODUCT

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ABSTRACT

In this study, response surface methodology (RSM) was used to obtain the optimum formulation for the chicken roll product to achieve the desired quality characteristics. The user defined experimental design was applied with three-variable and five replications in the center point, and the effects of the different amounts of ingredients that contained in the chicken rolls on the texture, color and cooking loss characteristics of the samples were investigated. Wheat flour (4 - 30%), distilled water (30 - 65%) and minced chicken (17 - 50%) were chosen as independent variables; and the responses were the hardness, adhesiveness, springiness, cohesiveness, gumminess, chewiness, resilience, *L**, *a** and *b** color values and cooking loss. Optimum formulation for chicken rolls was found as 6% wheat flour, 56% distilled water and 34% minced chicken depending on the levels of the selected quality characteristics.

Key Words: *texture, food formulation, chicken roll, optimization*

INTRODUCTION

Chicken meat is one of the most popular foods in the world due to its protein content and less fat content compared to other meat products. In recent years, ready to eat (RTE) foods became one of the most preferred food products with changing consumers lifestyle, working both parents during long hours, convenience of consumption, spending less time for preparing meal and charm of flavorful products [1].

Starches take an important role in meat formulations due to the its unique white color, excellent mouth feel properties with bland taste and relatively smaller granules (2-7 µm) and it has become an alternative fat replacer which is also used to obtain good textural properties for food products [2, 3]. Since gum increases the viscosity of starch and affects the gelatinization, the utilization of gum and starch in food systems has been studied in several studies [4, 5]. The positive interactions between gums and starches improve the rheological properties of final product quality, and may decrease the cost of the products [5, 6].

In previous studies, chicken rolls were produced and analyzed with different formulations and methods [7–13]. However, to the best of our knowledge, there was no published study determined the textural properties for an optimized chicken roll. The purpose of this study was to optimize quantities of ingredients for a chicken roll product and evaluate the textural properties.

MATERIALS and METHODS

The skinless chicken breasts were obtained from Keskinoğlu Poultry and Hatchery Ind. Inc., Manisa, Turkey. The chicken rolls were prepared based on different formulations shown in Table 1. Then, it was molded (internal diameter of 10 cm) into roud shape and put into sealed plastic bags, and cooked in a 90°C water bath for 5 min (internal temperature of 72°C). Design-Expert version 7.0.0 (State-Ease Inc., Minneapolis, MN, USA) was used for optimization.

Table 1. Variables and their levels in Response Surface Design

Independent variables	Symbols	-1	0	1
Wheat flour (%)	X_1	4	17	30
Distilled water (%)	X_2	30	52.5	65
Minced chicken (%)	X_3	17	33.5	50

Texture profile analysis of chicken rolls was performed using TA.XT Plus Texture Analyzer (Stable Micro Systems, UK). Uniform four test samples with 25 mm diameter were cut from each chicken rolls for the texture profile analysis and the test samples were compressed twice to 50% of their original height using 36 mm cylindrical probe (P/36R) at a test speed of 10.02 cm/min. Force-time deformation curves were acquired with 50 kg load cell. The curves were calculated using Texture Exponent 2.0.6.0 software (Stable Micro Systems).

RESULTS and DISCUSSION

Results of texture profile analysis were shown in Table 2. Hardness values of chicken rolls were between 57.410 N and 123.069 N. It was observed that the variation of wheat flour (X_1) did not significantly affect the hardness of the samples (p>0.05) while the amounts of distilled water (X_2) and chicken (X_3) had a significant effect on the hardness of the rolls (p<0.05).

The linear regression model for hardness was as follows:

$$\boldsymbol{Hardness} = +\mathbf{549.22} - (\mathbf{557.63}\mathrm{X2}) - (\mathbf{453.86}\mathrm{X3})$$

Adhesiveness results of samples ranged from -0.018 N.min to -0.003 N.min. Only the linear effects of the independent variables had significant effects on the adhesiveness of the rolls. It was determined that wheat flour (X_1) and distilled water (X_2) had linear effects on the response of the independent variables (p<0.05). It was determined that there was no significant effect of chicken (X_2) on the model (p>0.05).

$$\boldsymbol{Adhesiveness} = (+\mathbf{0.18}) - (\mathbf{0.21}\mathrm{X1})) - (\mathbf{0.22}\mathrm{X2}))$$

Springiness and cohesiveness values of chicken rolls were between 0.796-0.900 and 0.739-0.818, respectively. Gumminess values of chicken rolls ranged from 46.509 N to 94.217 N. It was seen that only the linear effects of the parameters were significant on the response (p<0.05). Decreasing quantity of wheat flour or increasing quantity of distilled water provided less gummy chicken rolls. Similarly to gumminess, the linear effect of wheat flour and distilled water were statistically significant for the chewiness of chicken rolls.

$$\boldsymbol{Chewiness} = +\mathbf{546.46} - (\mathbf{377.44}\boldsymbol{X}\mathbf{1}) - (\mathbf{557.07}\boldsymbol{X}\mathbf{2}) - (\mathbf{478.53}\boldsymbol{X}\mathbf{3})$$

The results of hardness values were similar, and cohesiveness and gumminess relatively higher than the values of turkey roll reported by Tang et al. [14]. These differences for cohesiveness and gumminess could be related to cooking methods and food additives used in this study. Resilience values of chicken rolls were between 0.328 and 0.417. Wheat flour, distilled water, and minced chicken had a linear effect individually which were statistically significant for the model of resilience.

$$\boldsymbol{Resilience} = +\mathbf{2.18} - (\mathbf{1.85X1}) - (\mathbf{1.90X2}) - (\mathbf{1.87X3})$$

Table 2. Design and Results of Box-Behnken Experiments (Texture profile analysis (TPA))

Runs	X_1	X_2	X_3	Hard. (N)	Adh. (N.min)	Spring.	Cohes.	Gum. (N)	Chew. (N)	Res.
1	0	0	0	82.077	-0.007	0.874	0.776	63.918	56.298	0.362
2	0	1	-1	72.848	-0.015	0.803	0.767	55.889	45.065	0.351
3	-1	1	0	67.193	-0.009	0.883	0.774	51.914	46.218	0.370
4	0	0	0	85.947	-0.013	0.889	0.808	69.472	58.818	0.372
5	0	1	1	78.032	-0.018	0.845	0.739	57.384	49.187	0.328
6	1	0	1	110.629	-0.007	0.859	0.762	84.605	73.447	0.361
7	0	0	0	81.591	-0.008	0.796	0.786	63.968	51.408	0.383
8	1	-1	0	123.069	-0.010	0.840	0.753	92.152	77.474	0.368
9	-1	0	1	78.479	-0.009	0.878	0.773	60.679	53.317	0.374
10	0	-1	1	103.109	-0.003	0.900	0.786	80.905	72.685	0.392
11	1	1	0	83.436	-0.015	0.814	0.768	63.492	51.823	0.375
12	0	-1	-1	119.455	-0.010	0.877	0.786	94.217	83.165	0.408
13	-1	-1	0	86.515	-0.005	0.895	0.818	70.623	63.327	0.410
14	1	0	-1	108.615	-0.018	0.860	0.818	88.664	76.981	0.409
15	-1	0	-1	57.410	-0.006	0.848	0.812	46.509	40.315	0.409
16	0	0	0	91.872	-0.008	0.832	0.798	72.836	61.076	0.394
17	0	0	0	83.586	-0.008	0.821	0.805	67.320	55.864	0.417

X_1: Wheat flour; X_2 : Distilled water; X_3 : Minced chicken; Hard.: Hardness; Adh: Adhesiveness; Spring.: Springiness; Cohes.: Cohesiveness; Gum.: Gumminess, Chew.: Chewiness; Res.: Resilience

It was determined that there was no statistically significant difference between predicted and experimental values as a result of the chi-square test results and error rates (Table 3).

Table 3. Predicted Values and Experimental Values

	Predicted Values	Experimental Values	Error rate (%)
Hardness (N)	60.886	60.842	0.07
Adhesiveness (N.min)	-0.014	-0.014	2.00
Springiness	0.853	0.844	1.04
Cohesiveness	0.769	0.715	6.97
Gumminess (N)	46.508	45.524	2.11
Chewiness (N)	39.784	39.207	1.45
Resilience	0.356	0.331	7.12

Thus, regression models obtained using the response surface method have proven that the values of texture of chicken rolls can be estimated for any combination of chickens, distilled water and wheat flour ratio.

CONCLUSION

In recent years, interest in poultry products has increased and to meet this increasing demand in today's living conditions, different fast food products need to be developed. A limited number of studies have been conducted on optimizing new product development and determining textural properties of this

product. In this study, the most suitable formulation for chicken roll, which is a fast and healthy product in desired tissue and physical properties, has been developed. According to the results of this study, the wheat flour added to the formulation of chicken flour did not affect the hardness, while it decreased the chewiness, adhesiveness and resilience of the product.

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FOOD GROUPS: POULTRY

THE EFFECT OF BATTERS CONTAINING TRAGACANTH AND ZEDU GUM ON CHICKEN NUGGET PROPERTIES

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ABSTRACT

The chicken nugget is a battered food product which is prepared from white meat muscle coated with batter. The formulation of the batter usually consists of flours, spices, colorants, hydrocolloids (carboxymethyl cellulose, guar, xanthan gum, etc.) and water. The effect of various gums on the rheological properties of batters and the final product characteristics has been widely investigated. However, the current knowledge does not include the determination of the effects of Tragacanth gum (TG) and Zedu gum (ZG) usage on the rheological and physicochemical properties of chicken nugget batters. This study aimed to investigate the effect of addition of TG, ZG and xanthan gum on the rheological properties and quality attributes of chicken nuggets. The study found that the addition of TG caused a significant increase in the apparent viscosity and consistency index of the batters. In addition, the batter pick-up and cooking efficiency of the batters prepared with 1 and 1.5% TG showed the highest values, indicating the positive influence of TG on the quality attributes of the end-product. The highest correlation was observed between apparent viscosity and cooking yield. A high correlation coefficient was also observed between consistency index of batters and cooking yield. It can be concluded that that the ability of TG in increasing the viscosity of batters is dependent on its high water binding capacity which subsequently resulted in a high cooking yield value in chicken nuggets.

Key Words: *chicken nugget, batter, Tragacanth gum, Zedu gum, rheology*

INTRODUCTION

The past three decades have seen rapid development of convenient food products in industrial life of human. Battered and breaded food products are becoming popular among the world due to their particular organoleptic properties such as acceptable texture and mouth-feel, good taste and appearance [1]. The chicken nugget is a battered food product which is prepared from white meat muscle and coated with batter [2]. The batter consists of different ingredients including flours (wheat, corn and rice), spices, colorants, different starches and proteins (egg or gluten), hydrocolloids (carboxymethyl cellulose (CMC), guar, xanthan gum, etc.) and water [3]. Batter coating forms golden yellow crust on the surface of the product which can act as a protecting layer to prevent water loss from interior layers of the food [4].

Much of the current literature on battered and breaded products pays particular attention to the effect of various gums on the rheological properties of batters and *subsequently, final product* characteristics. Hydroxypropyl methylcellulose (HPMC), guar gum, xanthan gum, guar–xanthan combination, gum arabic and carrageenan were used in this field more than other hydrocolloids [5-7].

ZG (obtained from *Amygdalus scoparia* of Rosaceae) and TG (obtained from Asiatic species of *Astragalus*) are mainly found in central parts of Iran and Turkey [8]. TG has the number E413 in the European Union scientific committee list of food additives. Since 1961, in the USA, TG has been allowed to use safely at the level of 0.2–1.3% as GRAS in food products [9]. ZG is an arabinogalactan polysaccharide and non-Newton hydrocolloid which exists in three different colors: red, yellow and white. Among these three types of ZG, the white one has the highest average molecular weight, thermal capacity, shear sensitivity and the lowest dispersity [10]. To obtain documentary results and better comparison between previous researches, we involved xanthan in this research as a well-known hydrocolloid. Xanthan is a high molecular weight polysaccharide which is produced by *Xanthomonas campestris*. Xanthan is an o/w emulsion stabilizer and viscosifying agent in both hot and cold water. This gum is generally used in low fat food products due to its high water binding capacity [11].

This project was undertaken to evaluate the effect of TG, ZG and xanthan gum on rheological properties, oil absorption, moisture content and batter pick-up of chicken nugget.

MATERIALS and METHODS

Chicken Nugget Paste Ingredients

Table 1. The amount of raw ingredients in chicken nugget paste

Raw materials	Used amount (gr)
Chicken meat	76
Egg	0.97
Oil	1.22
Spices	0.97
Milk powder	0.37
Flour	0.97
Starch	0.97
Phosphate	0.24
Water	9.26
Soy protein	0.49
Breadcrumbs	4.87
Salt	1.22
Onion	2.44
Total	100

As mentioned in Table1, frozen, de-boned and skinless chicken breast and thigh muscles were provided by Tehran Makian Alwan poultry (Tehran, Iran). The following ingredients were also used for preparing chicken nugget paste: soy bean oil (Bahar Oil Co., Tehran, Iran; peroxide number<1 and moisture content<0.2%), wheat flour with moisture content up to 14.2% (w/w) and spices (Forouzesh Food Products Co., Tehran, Iran), pasteurized egg (TS=23.5%, pH=6.7, negative α-amylase activity) and milk powder (Bina Razan Co., Hamadan, Iran), salt (Sadaf Sepid Co., Tehran, Iran), starch (Shahdineh Aran Co., Isfahan, Iran), sodium phosphate (Dor Shimi Marjan Co., Tehran, Iran; purity 60%-71%), soy protein

with moisture content up to 5% and ash amount less than 4% (Maxsoy Co., Tehran, Iran), breadcrumbs (Ramshintord Co., Tehran, Iran) and onion (Golmohammadi Co., Hamadan, Iran).

Batter Ingredients

Whole pasteurized egg (TS = 23.5%, pH = 6.7), whole wheat flour (ash content ~ 1.4-1.6% dry based, moisture content up to 14.5% w/w) and red pepper were provided by Forouzesh Food Products Company (Tehran, Iran). Milk powder (Bina Razan Co., Hamadan, Iran) and breadcrumbs (Ramshintord Co., Tehran, Iran) were aslo purchased. The following hydrocolloids were used in the formulation: TG (*Astragalus Fluccosus* spp) from Semnan state, Shahrood city, Moojen village and ZG (*Amygdalus scoparia*, pure white color) from Fars state, Fasa city and xanthan gum from Merck KGaA (Darmstadt, Germany). Batter formulations are shown in Table 2.

Table 2. Formulation of batters

Ingredients	M_1	M_2	M_3	M_4	M_5	M_6	M_7
Wheat flour	80	79	78.5	79	78.5	79	78.5
Egg	10	10	10	10	10	10	10
Milk powder	5	5	5	5	5	5	5
Red pepper	5	5	5	5	5	5	5
Xanathan gum	0	0	0	0	0	1	1.5
Tragacanth gum	0	1	1.5	0	0	0	0
Zedu gum	0	0	0	1	1.5	0	0
TOTAL	100	100	100	100	100	100	100

Chicken Nugget Paste Preparation

Frozen chicken breast portions thawed at ambient temperature for 12 hours prior to conducting the experiments, and were cut by using a 30 mm meat grinder (Parchami, Iran). Frozen boneless thigh muscles were cut by using a 6 mm frozen meat grinder at -12°C. Minced breast and thigh muscles in a ratio of 4:1 were first mixed with water, salt and phosphate. Then, the other ingredients including milk powder,, spices and oil were added to the mixture. The nugget paste mixture was kept at -6°C for 24 hours in order to be ready for mold forming [12, 13].

Batter Preparation

Batter ingredients have been completely mixed. Powder ingredients were added slowly to water and liquid eggs, stirred together with electric mixer (Parchami, Iran) for 5 minutes in fast setting, and it rested for 15 minutes. Batter powder ingredients ratio to water was controlled at 3:5 [14].

Chicken Nugget Preparation

Chicken nugget samples were prepared continuously. Nugget paste was entered in molding machine (Stork, the Netherlands) at -2°C. First stage of coating was done by milling machine (Stork, the Netherlands), flour coated formed paste was dipped in batter manually and placed on conveyor till the extra batter on nugget was lost. In order to complete nugget coating, battered formed paste was coated with toasted flour (Stork, the Netherlands). Nugget samples were entered in 180°C fryer (Stork, the Netherlands) for 30 seconds, then 125°C oven (stork, the Netherlands) for 4.5 minutes. In the last stage, cooked nuggets were frozen quickly in -35°C for 45 minutes (Heinen, Germany) and manually packed

in polypropylene containers. Samples weights were measured in all stages and all data was recorded [13].

Rheological Properties of The Batter

Rheological experiments were carried out with a Physica MCR 301 rheometer (Anton-Paar, GmbH, Graz, Austria) using a concentric cylinder (CC27) probe. All of the rheological tests were performed at 25°C. In order to allow the temperature equilibration, all of the samples were allowed to rest for 2 min before the rheological measurements. All tests were performed in triplicate.
The flow curves of samples as a function of shear rate (0.01-500 s^{-1}) were obtained. The power law model (Eq. 1) was used to interpret the rheological properties of the samples. By fitting the shear rate versus apparent viscosity values, the flow behavior index (*n*) and consistency coefficient (*K*) values were calculated.

$$\eta_a = K\dot{\gamma}^{n-1} \quad (1)$$

Strain sweep tests were performed (0.01-1000%, 1 Hz) to determine the limiting value of linear viscoelastic range (LVE). Frequency sweep tests were performed using a frequency ramp from 0.01 to 20 Hz. The power law model (Eq. 2) was also fitted to frequency sweep data of the samples.

$$G' = a\omega^b \quad (2)$$

Where *G'* is storage modulus (Pa), *a* is constant coefficient (dimensionless), ω is angular frequency (rad/s) and *b* is flow behavior index (dimensionless).

Determination of Moisture and Oil Contents and Water Activity

The samples were dried in an oven at 103± 2°C for 30 minutes until the achievement of constant weights in order to measure the weight loss as the moisture content of samples [15]. The oil content was analyzed using a Soxhelet extraction system HT [15]. a_w sprint (TH500 aw sprint, Novasina, Switzerland) operates on the basis of manometer with the ability to establish more details in compare with other methods. In accordance to the instructions provided by the manufacturer for nugget a_w test, temperature of the internal chamber should be matched with laboratory temperature. Therefore, the system used correction factor automatically. After the calibration, internal part of the chicken nugget was grinded and 5-6 gr of sample were entered into sample container and after closing the system, the analyze order began for 15 minutes [16].

Texture Analysis

Textural properties of samples were evaluated by a texture analyzer (*TA-CT3 Texture Analyzer, stable micro system, England*). Samples were fried at 270°C for 5 minutes (2.5 minutes each side) and were analyzed 45 minutes after frying. Puncture test with 50 N load cell using a conical probe (diameter = 4.5 mm) was used to evaluate chicken nugget texture. The peak force (F-max) required for penetration into 25% of the fried nugget depth, at a speed of 1 mm/s, was recorded [5].

Color Measurement

The whole nugget sample color was measured with the Hunter lab colorimeter (Color Flex model, America) calibrated with black and then white calibration plate. This examination was done triplicate. The whole nugget was fried for 5 minutes (2.5 minutes each side) in 270 ºC and prepared for this evaluation. Samples were entered in colorimeter respectively. Nugget color was measured by the Hunter lab plate light reflection with L^* parameter (brightness), a^* parameter (redness), b^* parameter (yellowness) and ∆E (total difference).

$$\Delta \boldsymbol{E} = \sqrt{\Delta \boldsymbol{L} + \Delta \mathbf{a} + \Delta \mathbf{b}} \quad (2)$$

It should be noted that these differences were calculated compared to standard values (Martelli, 2008).

Cooking Efficiency

Cooking efficiency was determined triplicate by the ratio of sample weight after being in oven to raw sample paste weight [16].

$$Cooking\ efficiency = \frac{sample\ weight\ after\ being\ in\ oven - raw\ sample\ paste\ weight}{raw\ sample\ paste\ weight} x100 \quad (3)$$

Batter Pick-up

Batter pick-up was considered to be the amount of batter adhering to the chicken nugget and it was calculated as the ratio of samples paste weights before and after coating [16].

$$Coating\ Pick\ up = \frac{sample\ paste\ weight\ after\ coating - sample\ paste\ weight\ before\ coating}{sample\ paste\ weight\ before\ coating} x100 \quad (4)$$

Sensory Evaluation

Sensory properties including color, flavor, texture and total acceptance were evaluate by 8 trained assessor of Alvan company quality control personnel by filling out 9 point hedonic scales questionnaire. In this scale, 1 referred to extreme disliking and 9 indicated extreme liking. Samples were coded by 5 digit random numbers.

RESULTS and DISCUSSION

Flow Behavior and The Viscoelastic Properties of The Nugget Batters

Nugget batter samples were given codes as shown in Table 2. Flow behavior of all samples is depicted in Fig 1. All batter samples demonstrated a non-Newtonian and pseudoplasticity nature at shear rate of 0.01–1000/s; the apparent viscosity of the samples decreased as the shear rate increased. This result was in agreement with that of previous studies on the exudative gum solutions [18, 19]. In order to compare the flow properties of the samples, the flow data were fitted to power law model and the values of flow index, consistency index, the apparent viscosity at 100 s^{-1} (η_{100}), were obtained (Table 3). Our study shows that the composition of batters significantly affects their rheological properties. The viscosity and consistency index of all batters increased by addition of hydrocolloids. The apparent viscosity of sample 3 at shear rate of 100 s^{-1} was significantly higher than other nugget batters (Table 3).The control sample displayed the lowest apparent viscosity and consistency index. In general, the addition of

hydrocolloids in all batters improved the quality attributes of chicken nuggets. The samples containing TG exhibited the highest apparent viscosity. Our results showed that the TG increase the viscosity of the batters in lower amounts compared to xanthan gum.

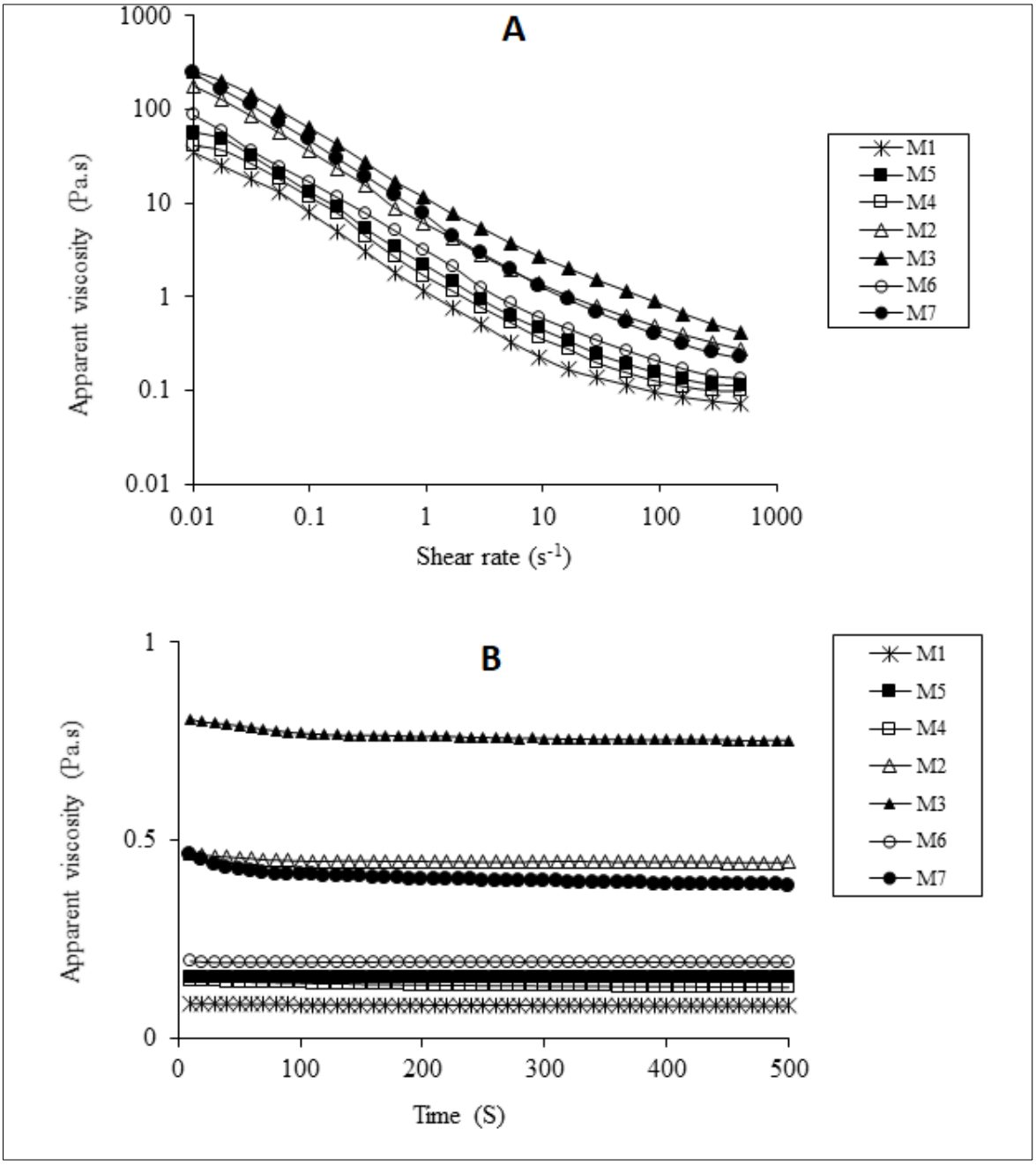

Figure 1. Flow curve and viscosity change with respect to time for the batters

Strain sweep tests were carried out (0.01-1000%, 1 Hz) to determine the LVE range. The crossover point ($G'= G''$) (Pa) for the end of LVE region has been obtained (Table 2). The batter sample prepared with 1.5% Tracaganth gum showed the highest crossover point indicating its more solid like behavior compared to other samples. The parameters of power law model which describes the frequency dependency of G' modulus of the puddings were obtained and are shown in Table 3. Here, the coefficient *a* represents the magnitude of G' and indicates the rigidity or structural strength, and the exponent *b* represents the slope of the relationship between modulus and frequency [20]. The M3 and

M7, containing the 1.5 % Tracaganth gum and 1.5 % Xanthan gum, respectively, showed the highest *a* value or structural strength. The M7 also exhibited the lowest *b* value which indicates its higher elastic behavior and frequency independency of G'.

Table 3. Rheological properties of batter samples. Numbers with different superscript letters within the same column are significantly different (Duncan post hoc test, $p< 0.05$). SD, standard deviation

Samples	Flow Behaviour			Frequency sweep		
	η_{app} (cP)	K (Pa.s^n)	n	$G' = G''$ (Pa)	K' (Pa)	K'' (Pa)
M_1	0.07±0.00^{f}	0.94±0.00^{fg}	0.53^{a}	4.07±0.01^{g}	2.32±0.01^{f}	0.21±0.01^{c}
M_2	0.44±0.01^{b}	3.88±0.22^{c}	0.47^{b}	10.03±0.03^{c}	4.65±0.01^{c}	0.33±0.00^{a}
M_3	0.74±0.04^{a}	8.45±0.09^{a}	0.46^{b}	26.05±0.00^{a}	13.64±0.05^{a}	0.31±0.00^{b}
M_4	0.12±0.02^{e}	1.00±0.03^{f}	0.54^{a}	5.1±0.06^{f}	2.37±0.01^{g}	0.20±0.00^{c}
M_5	0.14±0.00^{e}	1.13±0.02^{ef}	0.53^{a}	7.87±0.02^{d}	2.84±0.02^{d}	0.22±0.01^{c}
M_6	0.19±0.01^{d}	1.70±0.02^{d}	0.47^{b}	6.06±0.01^{e}	2.75±0.01^{e}	0.15±0.00^{d}
M_7	0.39±0.01^{c}	4.25±0.04^{b}	0.46^{b}	20.88±0.01^{b}	7.13±0.02^{b}	0.02±0.00^{e}

In order to investigate the effect of rheological properties of batters on the properties of chicken nuggets, the relationship between cooking yield, a_w, oil absorption and moisture content was modeled by simple regression; the correlation coefficients between the parameters are shown in Table 3. As indicated in Table 3, the highest correlation (0.0978) is observed between apparent viscosity and cooking yield. A high correlation coefficient (0.9265) is also observed between consistency index and cooking yield. The ability of hydrocolloids in increasing the viscosity is dependent on their water binding capacity. Viscosity development within the batter may be explained by the water binding capacities of the dry ingredients. If the hydrocolloid binds a significant amount of moisture, it will provide higher consistency to the batter. Because of their higher water-binding capacities, hydrocolloids develop consistency in batter systems, helping to trap gas evolved by the fast action of leavening agents. This results in a higher volume and improves the texture of the fried products.

Water Activity

The results showed that with increasing the nugget moisture content, water activity increased. Gum type and concentration had a significant effect on the nugget water activity (p<0.01). Nugget samples containing TG had the highest water activity followed by nugget samples containing xanthan. The control sample showed the lowest water activity.

Batter Pick Up

According to our results, gum type and its concentration had a significant effect on the batter pick-up. It is generally accepted that batter pick-up is directly related to the batter viscosity. The M3, M2 and M7 containing 1.5% TG, 1% TG and 1.5% xanthan, respectively, which exhibited the highest viscosity, increased batter pick up significantly and exhibited highest batter pick-ups as well. Control sample showed the lowest batter pick up value. In automatic system of breading and battering, a little difference in viscosity can cause unacceptable changes in batter pick up. Thus monitoring the viscosity and rheological behavior of the batters plays a key role in the quality of the end product. In a study on the effect of Hydroxypropyl methylcellulose gum (HPMC), xanthan gum, and pregelatinized starch on the properties and quality of chicken nuggets, Altunakar et al. [5] reported demonstrated that coating pick-up was positively correlated with viscosity and consistency of the batters. Chen et al. [4] reported a

strong positive correlation between consistency and batter pick-up in fish nuggets containing 1% CMC and 1% HPMC. They indicated that the adherence properties of batters containing 1% HPMC improved as a result of their increased viscosity.

Chicken Nugget Cooking Efficiency

According to our results, the concentration and type of the gum have a significant effect on the cooking efficiency of the nugget samples. Sticky batters which contain polysaccharide gums can cause a viscous layer on the surface of the product. Batter starch gelatinized in the batter and prevents mass transfer from nugget during the frying process and decrease cooking loss [21]. There has been a significant difference between the cooking effiency of all of the samples. Nugget samples containing 1.5% TG, 1% TG and 1.5% ZG showed the highest cooking efficiency respectively. The lowest cooking efficiency was attributed to control sample.

Moisture Content

Previous works have shown that the addition of gums to the nugget batter formulation increases the water retention of batters due to the formation of hydrogen bonds between water and gum molecules [11]. The increase in water binding caused an increase in the viscosity of batter which in turn imparts in the production of a juicier final product [5]. Our results demonstrated that the gum type had a significant effect on the nugget moisture. Batters containing 1 and 1.5% TG have the highest moisture content and viscosity compared with batters with ZG and xanthan.

Oil Content

Nugget fat content is the total of the initial nugget paste fat and the amount of oil absorbed during the frying process. Since the nuggets paste fats are equal in all nugget samples in this study, the final fat content will be directly related to the oil absorbed during the frying. Nugget batters prepared with ZG and TG showed the highest and the lowest fat content, respectively. Among the batter samples, control sample had the highest fat content and the batters prepared with 1% and 1.5% TG had the lowest fat level. No significant differences were observed between treatments containing ZG and xanthan. The batters containing 1 and 1.5% TG showed the highest moisture content and lowest oil content. This is probably due to the fact that TG can form a gel structure which increase the moisture retention and decrease the oil absorption. Altunakar et al. [22] stated that the viscosity of batters is negatively correlated with oil content of chicken nuggets. They reported that low oil content of fried chicken nuggets with added HPMC is probably due to the high apparent viscosity of HPMC which provides an effective barrier for oil uptake. This is in consistent with our results and the chicken nuggets prepared with TG which the highest viscosity had showed the lowest oil content.

Texture Analysis

The usage of food gums in the batter formulation is a common practice due to their texturizing capabilities. Overall, control sample showed the highest F-max and firmest texture. Among the gum-added chicken nuggets, the batters containing ZG and xanthan gum had the highest and lowest F-Max, respectively. Similarly, it was reported that the Xanthan gum provides soft texture to the fried chicken

nuggets which is probably due to its water holding capacity. It has been reported that the addition of gums to batters improves the texture and flexibility of the fried batters by improving the film-forming abilities of coatings. According to previous researches it was determined that using gums in nugget batter cause improvement in the nugget texture rather than using starch which can be as a result of more water holding capacity of gums [22]. For examples, xanthan gum caused more tenderness than CMC in fried nuggets [11].

Sensory Evaluation

Regarding to color values, there weren't any significant differences between treatments and control sample (p>0.05). But control sample got the lowest score and nugget sample with 1% TG got the highest score from assessors. Kilinççeker [21] used CMC in chicken nugget batters and got the same result [21]. But gum type and its amount have very important roles in nugget color (p<0.01). The control sample has the highest level of color and the sample with 1.5% TG has the lowest level of color in Hunter lab colorimeter test. So this result doesn't confirm assessors evaluation. There isn't any significant difference between nugget samples and control sample in flavor evaluation (p>0.05), type and amount of gum did not affect nugget flavor significantly. This result is in accordance with the results reported by Kilinççeker [21]. The mean values of the type and the gum amount in nugget samples didn't show any significant differences between nugget samples and control nugget in texture properties (p>0.05). Nugget sample with 1.5% TG got the highest score from assessors in sensory evaluation. It seems that nugget samples with different amount of gums don't have significant differences in total acceptance (p>0.05). Nugget sample with 1.5% TG got the highest score from assessors.

CONCLUSION

Batters containing 1.5% TG provided higher viscosity, higher batter pick-up values, higher moisture content and lower oil content. The addition of gums to batter formulations had a significant effect on the batter pick-up, oil content, rheological and textural properties of chicken nuggets. Batter viscosity correlated well with the cooking efficiency of fried chicken nuggets. Considering the quality and rheological attributes of chicken nuggets formulated with different gums, TG can be recommended for use in the formulation of batters in order to produce a product with low oil content and good texture and sensory properties.

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FOOD GROUPS: CONFECTIONARY

EFFECT OF MALTITOL AND XYLITOL COMBINATION ON PHYSICOCHEMICAL PROPERTIES OF SUCROSE-FREE CHOCOLATE

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ABSTRACT

The demand for products with low sucrose content is increasing, because of diabetics attitudes towards sweetness. In this study, sugar alcohols (maltitol and xylitol) at different levels (0, 25, 50, 75 and 100%) were substituted for the sucrose in milk chocolate formulation. The resulted samples were evaluated for their physio-chemical and sensory properties. The mixture design was used for optimization of sucrose substitutes in the formulation. The increasing maltitol concentrations with simultaneous reduction in xylitol resulted in consistent decrease in the Casson viscosity and flow index while led to increases in Casson yield stress. Overall, the sample containing 100% maltitol was the hardest (6.75 N) compared to the control (6.43 N). Chocolate samples containing 100% maltitol and the control had the highest acceptability. Taking all quality properties into account, formulation consisting of 28.24 gr maltitol and 4.76 gr xylitol had the maximum desirability. The results indicated that sucrose substitution by bulking agents have potential as a pleasant food in the formulation of diabetic/reduced calorie milk chocolates.

Key words: *chocolate, diabetic, maltitol, xylitol*

FOOD GROUPS: CONFECTIONARY

RHEOLOGICAL CHARACTERIZATION OF CARAMELIZED CHOCOLATE

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ABSTRACT

Chocolate is a popular product in the world consumed by people of all age with pleasure. Phenolic compounds present in their content give their own taste. Depending on the differences in composition of cocoa mass, milk fat and cocoa butter; there are varieties such as bitter, milk and white chocolates. White and milk chocolates can be obtained by addition of cacao butter, milk products, lecithin and sugar. Their production is carried out by a series of processes (mixing, refining, conching and tempering) which provide the characteristics of chocolate. The type and quantity of raw materials cause differences in the production process, which influences quality parameters of final product. Chocolate and its products can be used in many different areas. One of these is caramelized white chocolate. It can be used as ganache, filling or tablet chocolate. Caramelized chocolate is obtained by caramelization of the white couverture by the reaction of the Maillards a result of temperature treatment. Since the obtained product has a semi-fluid structure, the rheological properties of chocolate are of great importance in terms of process and product quality. In this study, the rheological properties of the samples employed to heat treatment at 110°C for different time periods. After treatment at 110°C, it had a sandy / chalky structure and did not lose the classic white color, but after 90th minutes of treatment semi-fluid and brown color was observed. Rheological analyses were conducted at 60°C.Caramelized white chocolate exhibited pseudo-plastic flow with decreasing viscosities due to increased shear rate. Ostwald de Waele model well described the flow behavior of the samples with R^2 values (0.949-0.990) close to unity. Consistency index (K) and flow behavior index (n) values of the caramelized white chocolates changed between 12.17-25.01 Pa.s^n and 0.561-0.707,respectively. In addition, the effect of temperature on the apparent viscosity at 50 s^{-1} was also observed within temperature range of 25°C and 80°C. As expected, viscosity decreased with increasing temperature. The findings of the present study indicated that temperature treatment time affected rheological properties of the caramelized sample as well as physical characteristics of the sample, considered during production to achieve the product with desired quality.

Key Words: *rheology, caramelized chocolate, temperature*

FOOD PROCESSING

ISOLATION OF OKRA POLYSACCHARIDES BY ULTRASOUND ASSISTED EXTRACTION

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ABSTRACT

Okra (*Abelmoschus esculentus L.*), also known as lady's fingers, bamya/bamia, gumbo, or bhindi, is a plant of the *Malvacae* family and its water extracts contain thick slimy polysaccharides. The aim of this study is to obtain okra polysaccharides by ultrasound assisted extraction process and to investigate some physical, chemical, thermal and rheological properties of polysaccharides which can be use in the food industry. At the beginning part of study, extract was obtained from dried okra powder after 5, 10 and 15 minutes ultrasound extraction processes. The extract was centrifuged at 2000 g for 15 minutes and then concentrated on a rotary vacuum evaporator for 25 minutes at a rotation speed of 100 rpm and at 72-74°C. After that, for the purpose of purification ethanol was added and centrifugation was applied at 5000 rpm and 25°C for 10 minutes. The resulting polysaccharides were dried by freeze drying method at -45°C during 24 hours. Afterwards, some properties of these polysaccharides were determined by performing bulk density, compressed density, water retention capacity, SEM analysis, DSC, FTIR and rheological measurements on dried okra polysaccharides.

Keywords: *okra, polysaccharide, extractions, purification*

INTRODUCTION

Okra (*Abelmoschus esculentus L.*), also known as lady's fingers, bamya/bamia, gumbo, or bhindi, is a plant of the *Malvacae* family. It plays a part in the diet of Africa, the Middle East, southeast Europe, India, Pakistan, the southern United States, the Caribbean, Japan and Philippines among other countries [1].

Carbohydrates are present in the form of mucilage. That of young fruits consists of long chain molecules with a molecular weight of about 170,000 Da which are made up of sugar units and amino acids. The main components are galactose (25%), rhamnose (22%), galacturonic acid (27%) and amino acids (11%). The mucilage is highly soluble in water and has an intrinsic viscosity value of about 30% [2].

Its water extracts contain thick slimy polysaccharides and are used to thicken soups and stews. In recent years, polysaccharides are suggested to possess various pharmaceutical activities including increased immunity, anti-fatigue, anti-tumor, as well as anti-oxidation, lowering blood pressure, etc. Okra polysaccharides are also used as egg white substitute, fat substitute in chocolate frozen dairy dessert, and in chocolate bar cookies [3].

Ultrasound presents several advantages in terms of shortening the time of the process, decreasing the volume of the solvent, and increasing the yield of the extract in comparison with conventional methods.

Also, some applications of ultrasound in the food domain are presented, as well as an example of a green extraction [4]. For these reasons, okra fruits as material and utrasound assisted extraction as method was chosen.

MATERIALS and METHODS

Fresh okra samples to be subjected to extractions in the study were obtained from a local market in the province of Izmir. Ethanol was purchased from Merck (Darmstadt, Germany) for extraction of the polymers. Fresh okra samples were dried to content of about 5% moisture by using a laboratory-scale tray dryer (EKSIS Industrial Drying Systems, Isparta, Turkey) at 40°C with 1 m/s air velocity and 8 rpm rotational speed. Then it was milled using a hammer mill and the powder product was transferred to plastic bags and stored at room temperature until the extraction process.

Isolation of Okra Polymers (Extraction)

In this project, the method is modified and used which given by Zhai et al. [3]. Distilled water (1:25g/mL) was added to okra powder and allowed to stand for about 10-12 hours. Ultrasonically assisted extraction was performed using a probe type ultrasonic device (Hielscher UP400S, 24 kHz, Germany) and H14 (14 mm diameter, 90 mm height) probe at 15°C in a 250 ml double-hulled glass sample vessel. The energy (ultrasonic power) of the ultrasonic apparatus was recorded instantaneously with a wattmeter (Voltcraft Energy Check 3000, Germany). Extraction was carried out by using a water bath for temperature control, applying 200 W power for 5, 10, 15 minutes. The extract was centrifuged at a rotation speed of 2000 g for 15 minutes. The separated supernatant fractions were combined, filtered through fine muslin cloth and concentrated in a rotary vacuum evaporator (100 rpm, 72-74°C, 25 minutes). About 8 times the volume of ethanol was added to concentrated polysaccharide-containing solution followed by centrifugation was applied at 5000 g for 10 minutes. The obtained polysaccharides were dried by freeze drying (-45°C, 24 hours).

Analyzes

- Determination of Rheological Properties of Polysaccharide Solutions Prepared at Different Rates
- Determination of Water Holding Capacities of Polysaccharide Solutions Prepared at Different Rates
- Flow Behavior
- Density
- Bulk and Tap Densities
- SEM
- FTIR
- DSC

RESULTS and DISCUSSION

After the analyzes were done for the obtained polysaccharides after 5, 10 and 15 minutes extractions, the bulk densities were 305.578 kg/m^3, 317.952 kg/m^3 and 341.779 kg/m^3, the tap densities were 369.911 kg/m^3, 344.717 kg/m^3 and 398.742 kg/m^3; water holding capacities were determined as 3.430,

3.045 and 3.01; the densities were found as 1469.61 kg/m^3, 1465.66 kg/m^3 and 1472.26 kg/m^3, respectively.

Flow behavior of okra polysaccharide solutions prepared at different concentrations in the performed project was determined by flow test at 25°C. The shear rate-shear stress graphs of the solutions prepared at different concentrations are shown in Figure 1.

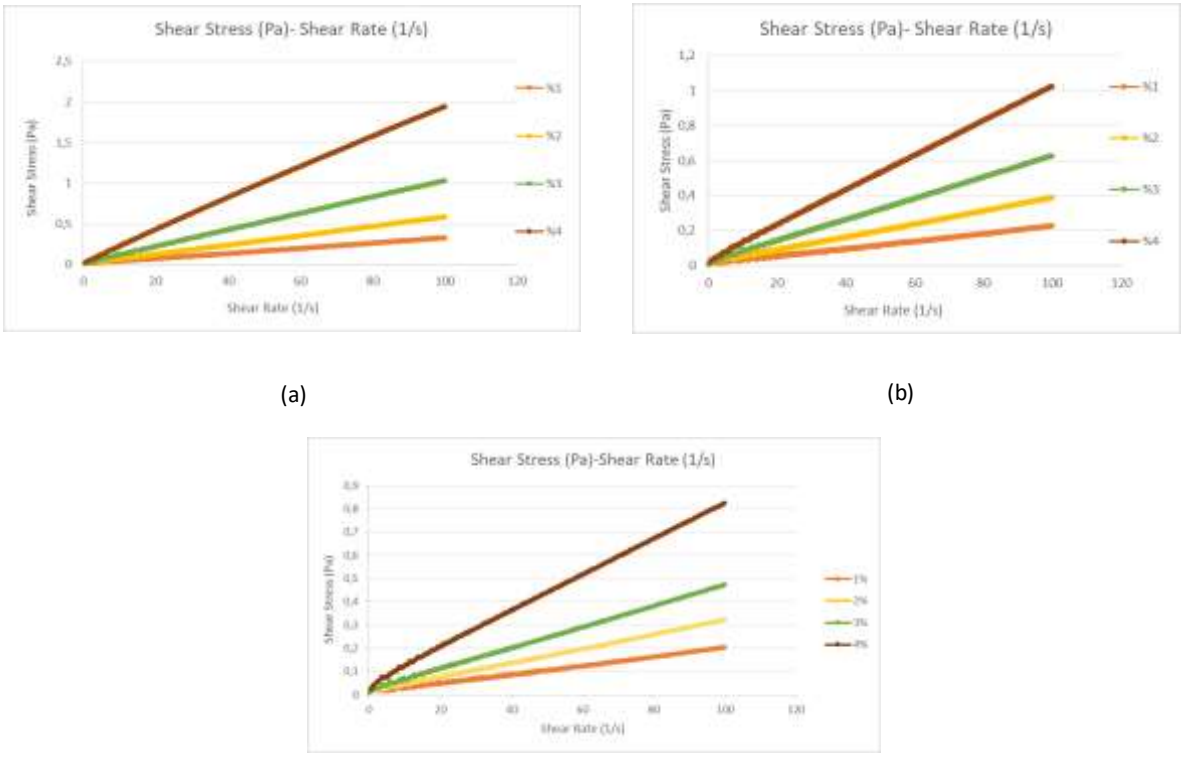


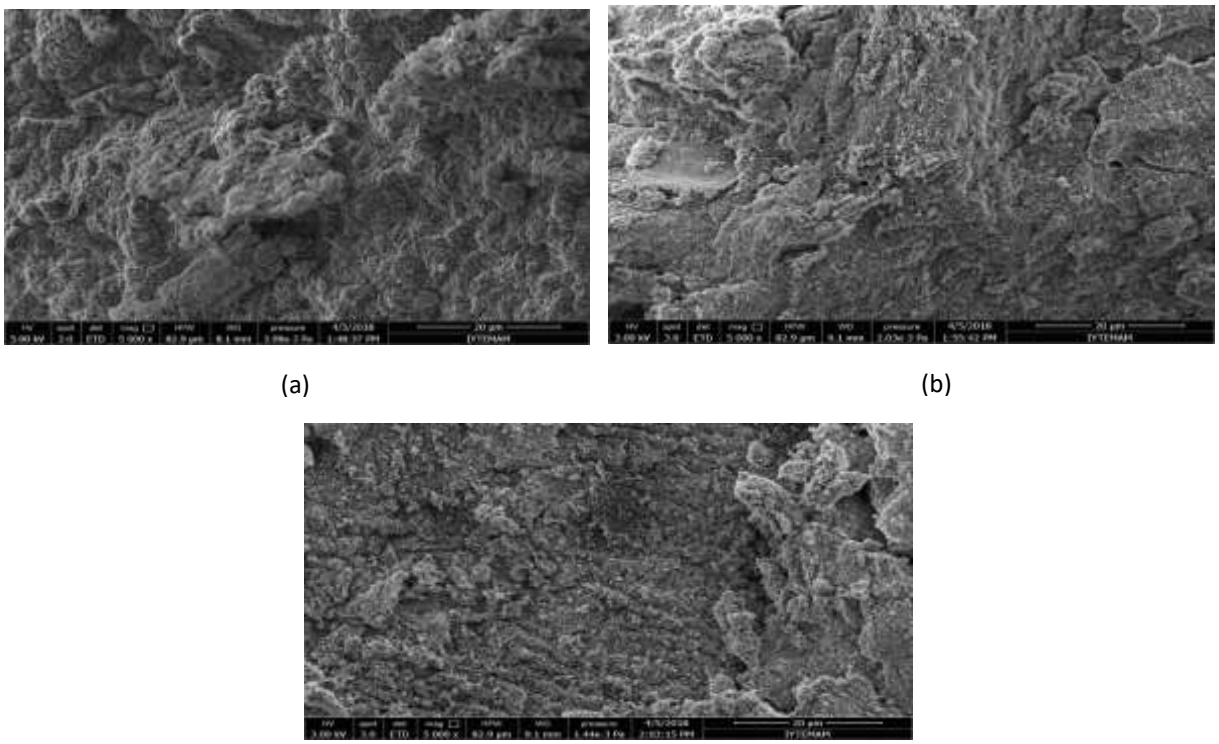
Figure 1. Shear stress (Pa)- Shear rate graphs for polysaccharides solutions at different concentrations prepared from the polysaccharides obtained after 5 (a), 10 (b) and 15 (c) minutes ultrasound assisted extraction processes

When the flow behavior characteristics of the solutions at different concentrations (1, 2, 3, 4 w/v) of the extracted polysaccharides were examined, it was determined that the shear stress of the solutions increased as the concentration of the polysaccharide solution increased at same shear rate values. Power Law, Herschel Bulkley and Bingham models were tested to determine the flow characteristics of the polysaccharide solutions formed at different concentrations, and models that bestly represent flow behavior for all samples were identified (Table 1).

Table 1. The coefficients calculated from the models used to determine the flow properties of the solutions prepared from polysaccharides obtained after 5, 10 and 15 minutes of ultrasound extraction

Time (min)	Conc. (%)	Models	Consistency Coefficient K (Pa.s^n)	Flow Behavior Index n	σ_0 (Pa)	R^2	RMSE
5	1	Power Law	0.004	0.937	-	0.999	5.769
		Herschel-Bulkley	0.003	1.032	0.012	0.999	0.095
		Bingham	0.003	-	0.009	1.00	0.078
	2	Power Law	0.007	0.962	-	0.999	0.007
		Herschel-Bulkley	0.005	1.028	0.017	1.00	0.320
		Bingham	0.006	-	0.012	1.00	0.017
	3	Power Law	0.012	0.958	-	1.00	0.0120
		Herschel-Bulkley	0.010	0.994	0.016	1.00	0.555
		Bingham	0.010	-	0.018	1.00	0.013
	4	Power Law	0.024	0.937	-	1.00	0.010
		Herschel-Bulkley	0.023	0.943	0.005	1.00	0.010
		Bingham	0.018	-	0.041	1.00	1.018
10	1	Power Law	0.003	0.926	-	0.994	0.009
		Herschel-Bulkley	0.002	1.069	0.014	0.996	0.115
		Bingham	0.002	-	0.009	0.996	0.006
	2	Power Law	0.005	0.926	-	0.999	0.015
		Herschel-Bulkley	0.003	1.020	0.016	0.999	0.078
		Bingham	0.004	-	0.014	0.999	0.018
	3	Power Law	0.009	0.928	-	0.999	0.011
		Herschel-Bulkley	0.006	0.995	0.018	1.00	0.657
		Bingham	0.006	-	0.020	1.00	0.016
	4	Power Law	0.014	0.922	-	0.999	0.013
		Herschel-Bulkley	0.011	0.974	0.024	0.999	0.537
		Bingham	0.0095	-	0.032	0.999	0.011
15	1	Power Law	0.003	0.903	-	0.994	0.010
		Herschel-Bulkley	0.001	1.089	0.015	0.999	0.017
		Bingham	0.002	-	0.010	0.998	0.011
	2	Power Law	0.005	0.903	-	0.997	0.006
		Herschel-Bulkley	0.003	1.021	0.015	0.999	0.013
		Bingham	0.003	-	0.014	0.999	0.016
	3	Power Law	0.007	0.901	-	0.998	0.016
		Herschel-Bulkley	0.005	1.001	0.02	1.00	0.015
		Bingham	0.005	-	0.02	1.00	0.015
	4	Power Law	0.015	0.869	-	0.999	0.010
		Herschel-Bulkley	0.011	0.942	0.041	1.00	0.034
		Bingham	0.009	-	0.052	1.000	0.010

Scanning electron microscopic (SEM) images (Fig. 2) revealed irregular, rough surfaced, and amorphous structure is the same for all okra polysaccharides which obtained from 5, 10 and 15 minutes ultrasound extraction.



(a) (b)

(c)

Figure 2. SEM pictures of okra polysaccharides powder obtained from 5 (a), 10 (b) and 15 (c) minutes ultrasound assisted extraction processes

The main components of okra which are galactose, rhamnose and galacturonic acid were determined in the spectrum of FTIR analysis as shown in Figure 3.

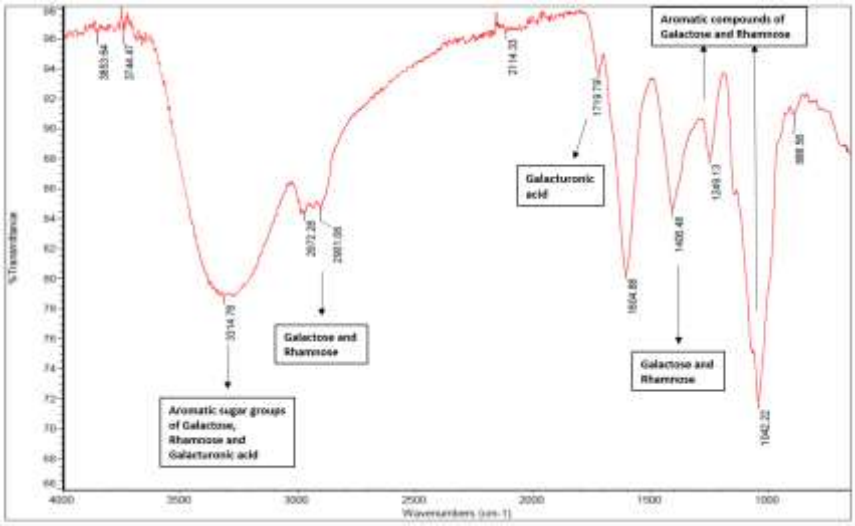


Figure 3. Composition of okra polysaccharides by FTIR (Fourier transform infrared spectroscopy)

Melting point (T_m), enthalpy (ΔH), glass transition (T_g) values of polysaccharides obtained after 5, 10 and 15 minutes ultrasound assisted extraction process were found as 173.715±0.665°C, 218.55±0.45 J/g, 51.945±0.135°C; 169.435±0.805°C, 221.65±0.25 J/g, 52.775±0.425°C; 173.095±0.245°C, 226.05±2.05 J/g, 51.445±0.125°C, respectively.

CONCLUSION

In the study conducted, polysaccharide extraction from dried okra was carried out. The physical, chemical, thermal and rheological properties of the obtained polysaccharides have been investigated. After the analyzes which were performed to investigate physical properties, the bulk densities were 305.578 kg/m^3, 317.952 kg/m^3 and 341.779 kg/m^3; the tap densities were 369.911 kg/m^3, 344.717 kg/m^3 and 398.742 kg/m^3; the densities were found as 1469.61 kg/m^3, 1465.66 kg/m^3 and 1472.26 kg/m^3 for okra obtained polysaccharides after 5, 10 and 15 minutes extractions, respectively. These results were determined to be similar with the results given by Emeje et al. [5]. Water holding capacities were determined as 3.430, 3.045 and 3.01. Chen et al. [6] obtained similar results for okra cholestin in the study which they done. It is seen that in the graphs, the solution with the highest concentration has the maximum shear stress value at the same shear rate. Also, it has been observed that the highest concentration solution has the highest viscosity value at the same shear rate. These are compatible with the given results from study made by Sengkhamparn et al. [7]. SEM images of polysaccharides which obtained from all process times show that they have irregular, rough surfaced, and amorphous structure and this structure is specified by Zaharuddin et al. [8] and Nagpal et al. [9]. According to FTIR results it is proved that okra polysaccharides contains galactose, rhamnose and galacturonic acid and the study is done by Zaharuddin et al. [8] is supported these results. DSC results (melting point (T_m), ΔH, glass transition (T_g)) for polysaccharides obtained after 5, 10 and 15 minutes ultrasound assisted extraction process were found as 173.715±0.665°C, 218.55±0.45 J/g, 51.945±0.135°C; 169.435±0.805°C, 221.65±0.25 J/g, 52.775±0.425°C; 173.095±0.245°C, 226.05±2.05 J/g, 51.445±0.125°C, respectively. Zaharuddin et al. [8] found T_m as 180°C and T_g as 60°C and they are close to values which get from this study.

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FOOD PROCESSING: HEAT TREATMENT

EFFECT OF HEAT TREATMENT ON RHEOLOGICAL PROPERTIES OF ACTOMYOSIN

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ABSTRACT

From the nutrition and safety point of views, human generally cook foods of animal origin, among which are the meat and meat products. Cooking applies energy that denaturates proteins trapped within meat tissues as the temperature exceeds 30°C. To date the effects of heating treatment (at detailed temperatures) on rheological properties of the actomyosin isolated from Turkish beef has not been studied yet. Thus, the aim of this research is to determine the exact temperature that might be the starting point of: structure destabilization, gelling point, and fluidity or reduced viscosity point of the actmyosin (muscle protein: 200kDa), which in turn effect on the texture of cooked meat. Rheological measurements were performed using a rheometer (Anton Paar, MCR-302) attached with a parallel plate system at 1mm gap. Temperature ramp analysis was carried out at constant strain values of 0.1% and 1 Hz frequency from 4 to 90°C. According to the results, shear stress values of actomysion were stagnant up to 40°C, while the increasing change was observed at higher temperatures due to denaturation (structure deformation). In addition, change of G' and G'' values with respect to time at different temperature levels (20, 30, 40, 50 and 60°C) was also analysed to observe the effect of temperature level on denaturation time. G' values did not change with time at temperatures lower than 40°C, in spite the increase was observed at 40°C, and at higher levels such as 50 and 60°C. Change in the G' values began at 2.5 min, 1 min and 1.5 min for the temperatures 40, 50 and 60°C, respectively. It is suggested that actomysion elastic properties affected by a higher temperature but shorter time during heat treatment. SDS-PAGE patterns illustrate different proteins including actmyosin were experienced a profound change in their molecular weights that resulted either from the coagulation or fragmentation of the original protein structures. The findings of the present study indicated that rheology is an effective tool to determine critical temperature values for meat proteins which resulted in structural changes. Those changes eventually effect on the eating quality and mastication properties of meat and meat products as perceived by consumers, especially the elderly people.

Key words*: rheology, actomyosin, denaturation, viscoelastic*

FOOD PROCESSING: NANOTECHNOLOGY

EFFECTS OF POLYMER RHEOLOGY ON THE FIBER FORMATION AND MORPHOLOGY OF PECTIN NANOFIBERS

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ABSTRACT

Nanofibers can be obtained from synthetic and biopolymers by electrospinning technique. It is known that rheological behavior of the fiber forming solution is critical for jet initiation and stabilization. The aim of this research was to conduct rheological studies on pectin solutions in order to understand the rheological factors that affected their spinnability either used alone or as blends with a synthetic carrier polymer (PEO). Pectin solutions were prepared at two different concentrations (6 and 12% w/v) and the concentration of PEO solutions was 2% w/v. Pectin solutions were blended with PEO (with three different molecular weight) solutions at 1:1(v:v) ratio. Rheological measurements were conducted using a rotary rheometer. While pectin could not be electrospun alone, addition of PEO initiated jet formation. PEO addition increased elastic modulus, and lowered the phase angle. Results showed that, the molecular weight of PEO was a very important factor on the electrospinnability and only solutions that were prepared with PEO at the highest molecular weight produced continuous, non-beaded fibers. The underlying reason was found to be the high elastic modulus, high zero shear viscosity and low phase angle values of these solutions.

Key Words: *electrospinning, rheology, pectin, nanofibers*

INTRODUCTION

Electrospinning is an efficient and economical fiber production technique to convert polymer solutions or melts into fine jets, subsequently to fibers in nano or submicron sizes. Electrospinning can be applied to both biopolymers and synthetic polymers for the production of nanofibers [1, 2]. Although natural polymers can offer many diverse applications, the studies showed that formation of nanofibers from biopolymers is more challenging than synthetic ones. The underlying reason for this difficulty arises from the diversity of natural polymers [2-5].

Pectin, a polyelectrolytic heteropolysaccharide, is majorly used in food based applications, as gelling, thickening and stabilizing agent. Pectin also finds applications in non-food areas due to its low cost, non-toxic nature, abundance, biodegradability and biocompatibility. Electrospun pectin fibers have potential to be utilized in many applications such as engineered tissues [6, 7], antibacterial surfaces [8], vitamin encapsulation [9] and drug delivery applications [10]. However, it is very challenging to obtain pectin nanofibers by electrospinning technique due to insufficient chain entanglement and lack of elasticity, as in the case of most biopolymers. Pectin usually requires a synthetic based biodegradable carrier polymer

(PVA or PEO) to maintain jet stability for fiber formation [7, 11-13]. The role of carrier polymers on electrospinnability of pectin has not been elucidated yet, although different ideas exist [6, 11].
A number of studies have been conducted to relate the rheological properties of fiber forming solutions to fiber formation and morphology [14-17]. The exact reason of "beads-on-string" formation instead of uniform electrospun fiber production is still under investigation [18]. The presence and the number of chain entanglements, which alter the viscosity of the solution, are important factors in electrospinning process to maintain jet stability [14, 16]. Moreover, studies show that, 'spinnable' solutions should exhibit elastic properties [17, 19]. The elastic behaviour of fiber forming biopolymer solutions were studied by Regev et al. [20] and Rosic et al. [19] to relate this parameter to the fiber formation [19, 20]. On the contrary to many other studies, Rosic et al. [19] stated that, polymer solutions from which nanofibers are produced must show higher plasticity than elasticity to enable jet stabilization [19].

As different studies presented different views on which of the rheological properties are the main driving forces for fiber formation, there is still a need to elucidate the relation between rheology and electrospinnability of biopolymers. The aim of this study is to understand the role of rheology on fiber formation from pectin solutions (either used alone or as blends with a synthetic polymer) and on the morphology of resulting electrospun pectin nanofibers.

MATERIALS and METHODS

Pectin (GENU, CP Kelco) and poly (ethylene oxide) (PEO) at molecular weights of 600, 1000 and 2000 kDa (Sigma Aldrich and Acros Organics) were used. Pectin solutions, in concentrations of 6 and 12% (w/v), were prepared by dissolving the required amount in distilled water at 70°C and then kept stirred at room temperature overnight. PEO, in three different molecular weights (600, 1000, 2000 kDa), were dissolved at room temperature at a concentration of 2% (w/v). Pectin and PEO solutions were mixed at equal volume and left for overnight stirring at room temperature.

Rheological analyses were performed using a Kinexus Rheometer (Malvern Instruments Ltd, UK). A cone and plate (cone angle 4°, diameter 40 mm) and a parallel plate geometry (diameter 40 mm) were used for viscosity and oscillatory tests, respectively. All experiments were conducted at room temperature in triplicate.

Dynamic measurements were carried out to measure the viscoelasticity of the solutions. Firstly, the linear viscoelastic regions (LVR) of samples were determined to choose a strain value that will assure an intact network structure for all samples. An amplitude sweep test was performed for each sample at a constant frequency of 2 Hz and at 25°C with increasing shear strain from 0.1 to 1000%. During electrospinning process, polymer solutions are drawn by the electrical field, thus, the response of the solutions to % strain was used to determine elastic modulus (G'), and phase angle (δ) values. The zero shear viscosity of the solutions was determined using creep test. Samples were subjected to 0.1 Pa stress (within the LVR) for 5 minutes at 25°C.

An electrospinning machine (Inovenso NE300, Turkey) with a high voltage power supply and a syringe pump (New Era NE1000, Turkey) were used to spin solutions. The syringe tip was connected to an

electrical source and electrical voltage was operated between 18 and 22 kV. A ground collector plate was used to collect electrospun nanofibers. The distance from syringe tip to the collector was fixed at 20 cm. The spinning was conducted for 3 hours at a flow rate of 0.2 ml/h. Each trial was repeated three times.

Morphological properties of electrospun fibers were visualized by using a Scanning Electron Microscope (SEM) (EVO 40 series, Carl Zeiss, Germany). All samples were coated with gold by a sputter coater (SCD 005, Baltec) prior to analysis.

Data were analyzed statistically by SPSS Statistics Program version of 17.0. Tukey test was used to determine whether the results are significantly different or not (p<0.05).

RESULTS and DISCUSSION

Pectin solutions behaved Newtonian at low shear rates and showed pseudoplastic behaviour at high shear rates. The solution viscosity of the blends increased with the increase in the molecular weight of PEO (Figure 1). The high viscosities of blend solutions, compared to the viscosities of pectin only and PEO only solutions, might be attributed to the presence of synergistic interactions between two polymers. Blends also exhibited more pseudoplasticity. The onset of shear thinning was also observed earlier in the solutions containing PEO with higher molecular weights which might be explained by the occurrence of local chain associations. While the flow behavior and viscosity values of the solutions containing PEO at molecular weights of 600 kDa and 1000 kDa were similar to each other, the blends containing PEO at a molecular weight of 2000 kDa had much higher viscosity values and showed more pseudoplasticity. Zero shear viscosities were found to be increasing with the increase in pectin concentration and PEO molecular weight (Table 1).

Table 1. Zero shear viscosity and phase angle values of spinning solution

Polymer concentration (w/v)			Zero Shear Viscosity ** (Pa.s)	Phase Angle** (δ)	Fiber
Pectin	PEO*	Total			
0	PEO_{600}	1	0.02±0.00	44.42±3.37	Mostly Bead
	PEO_{1000}	1	0.03±0.00	63.45±4.63	Mostly Bead
	PEO_{2000}	1	0.11±0.01	72.44±2.00	Mostly Bead
3	-	3	$0.09±0.01^{a}$	$80.21±0.02^{a}$	No jet
	PEO_{600}	4	$0.45±0.09^{a}$	$82.03±0.07^{a}$	Beaded
	PEO_{1000}	4	$0.64±0.01^{a}$	$77.41±0.82^{a}$	Beaded
	PEO_{2000}	4	$2.14±0.20^{b}$	$63.69±1.00^{b}$	Smooth
6	-	6	$1.00±0.05^{\Phi}$	$85.23±0.89^{\Phi}$	No jet
	PEO_{600}	7	$1.36±0.0^{\Phi}$	$79.02±1.09^{\upsilon}$	Beaded
	PEO_{1000}	7	$2.49±0.6^{\Phi}$	$74.68±1.10^{\upsilon}$	Beaded
	PEO_{2000}	7	$5.41±0.56^{\upsilon}$	$64.60±1.22^{\int}$	Smooth

*PEO concentration was kept constant at 1% (w/v).
** Statistical analysis was performed within each pectin concentration (3% and 6% separately) for each column.

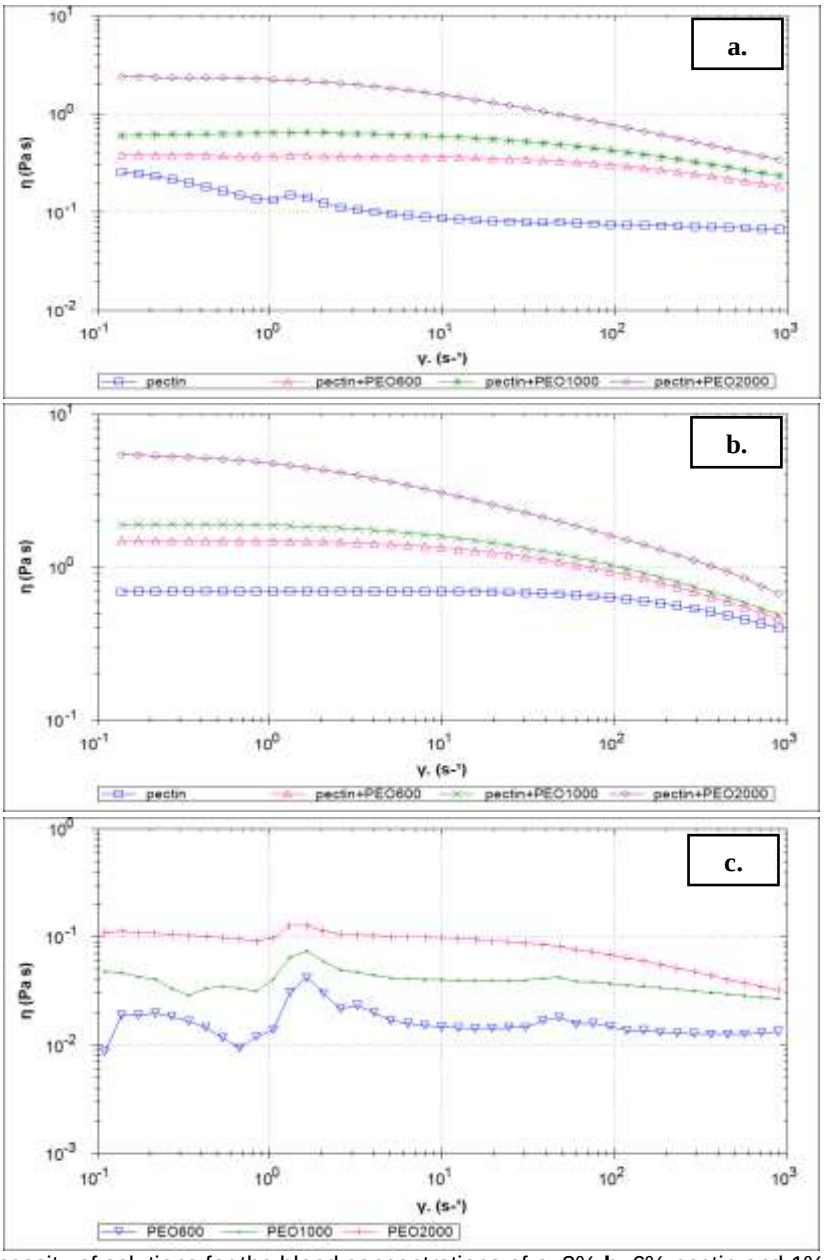

Figure 1. The viscosity of solutions for the blend concentrations of **a.** 3% **b.** 6% pectin and 1% w/v PEO. **c.** 1% w/v PEO solutions.

Figure 2 shows the elastic modulus (G') values of spinning solutions. Results showed that, PEO addition increases the elasticity of the samples which was more pronounced when PEO_{2000} was used in the blends. As can be seen in Figure 2c, the elastic modulus of PEO_{2000} stays constant for a longer range of % strain which can be attributed to a more stable structure.

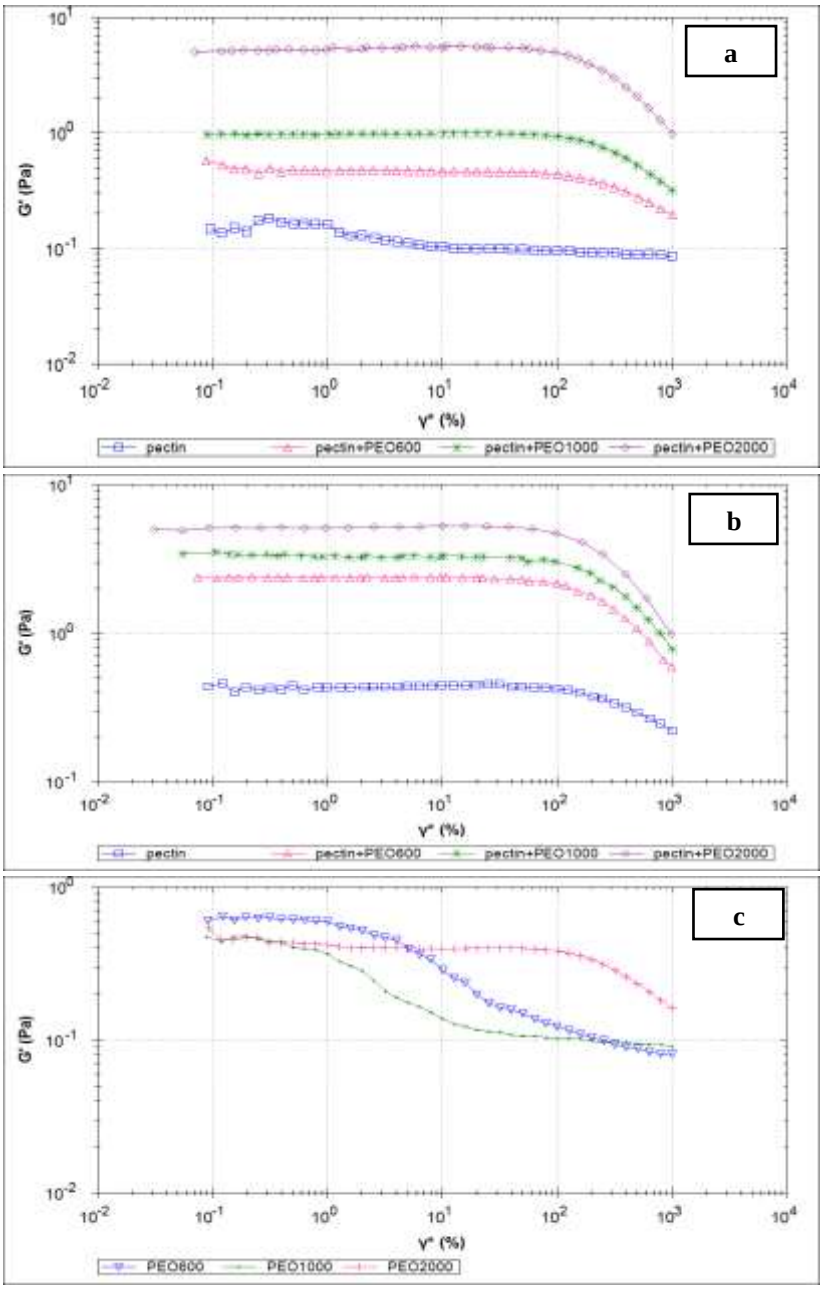

Figure 2. The elastic modulus values of solutions for the blend concentrations of **a)** 3% **b)** 6% pectin and 1% w/v PEO **c)** 1% w/v PEO solutions.

The phase angle (δ), a quantitative measure of solid-like and liquid-like structure, decreases with more solid-like behavior. The phase angle of pectin only solutions, PEO only solutions and pectin-PEO blends were higher than 45° for both concentrations, which means that the liquid-like character was dominant (Table 1). However, since PEO had lower phase angles compared to pectin only solutions, so did the blends. The elastic behavior of blend solutions were found to increase as the molecular weight of PEO was increased which was evidenced by a decrease in the phase angle. Pectin solutions generated only discontinuous droplets instead of continuous jets during electrospinning which indicates insufficient chain entanglements to maintain jet stability. On the other hand, when PEO was electrospun alone jet formation was observed but the fibers were mostly beaded. When pectin and PEO was blended, stable jet formation was achieved and fibers were able to gather on the collector.

Only beaded nanofibers were produced when PEO_{600} and PEO_{1000} were used in blends. However, continuous, smooth and non-beaded nanofibers were obtained at both pectin concentrations when pectin was blended with PEO_{2000}. This result may be explained by the changes in the rheological properties. Blends with PEO_{2000} had the highest zero shear viscosities (Table 1) and the onset of shear thinning was found to be early for these blends (Figure 1). In the blends with PEO_{2000}, since polymers align in the direction of shear this might have enhanced the chain entanglement in the microscopic level and ease the jet formation during electrospinning. Moreover, previous studies showed that high elasticity is required for a polymer to be electrospun [16, 17, 19]. Our results showed that, when pectin concentration was kept constant, elastic modulus values increased with the increasing molecular weight of PEO. Although PEO_{2000} addition increased the elasticity the most, comparing only G' values would be misleading to draw a conclusion about smooth fiber formation. Blends with PEO_{2000} had the lowest phase angles compared to other blends and pectin only solutions. On the other hand, although PEO only solutions also have low phase angles, due to their very low *G'* values, only beaded fibers were formed (Figure 3).

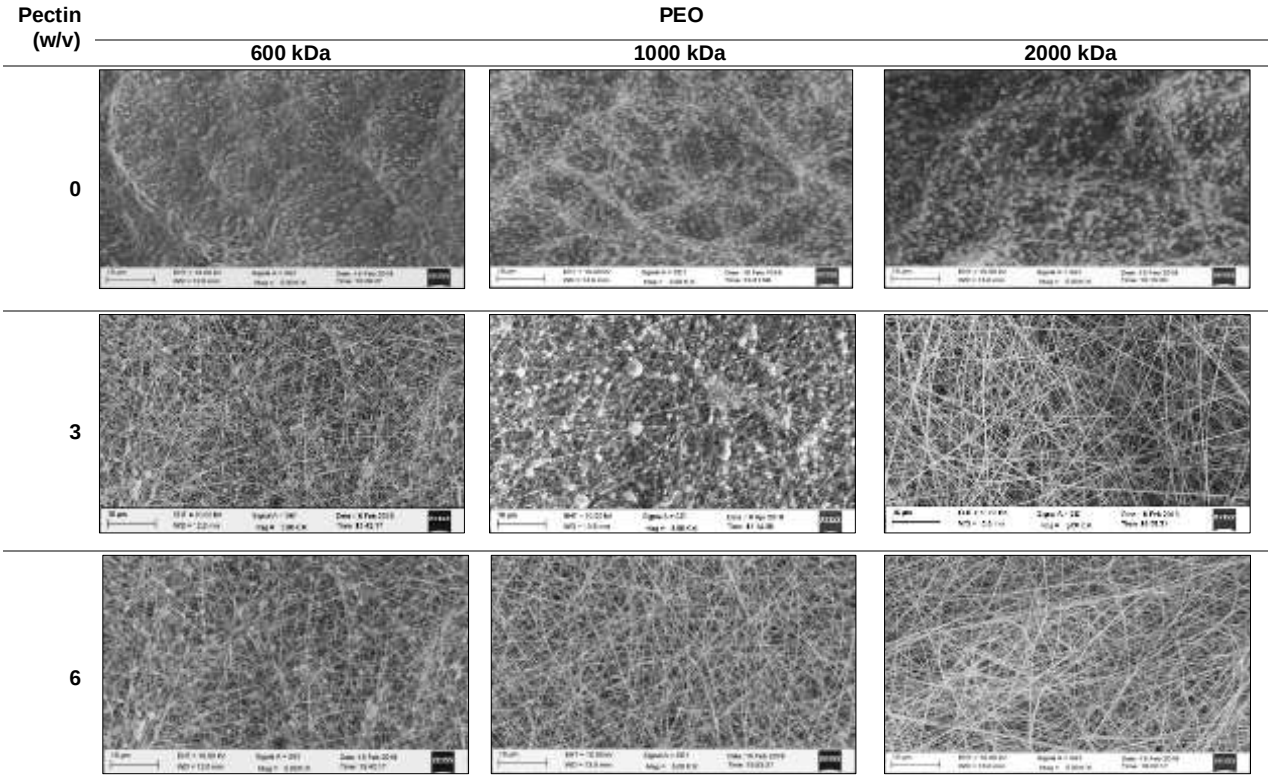

Figure 3. SEM images of nanofibers in solution concentration of 3% and 6% pectin and 1% (w/v) PEO in different molecular weights

CONCLUSION

In an attempt to understand the importance of solution rheology on formation of pectin nanofibers, PEO and pectin-PEO blend solutions were prepared at different concentrations and molecular weight. While pectin could not be electrospun alone, addition of PEO initiated jet formation. PEO, increased elastic modulus, and lowered the phase angle of pectin solutions, which in turn made fiber formation possible. However, although fibers were formed when blends were used, only solutions that were prepared with PEO at the highest molecular weight produced continuous, non-beaded fibers. The underlying reason

was found to be the high elastic modulus, high zero shear viscosity and low phase angle values of these solutions. Our results showed that different rheological parameters should be considered together to understand the relationship between the rheological properties of the spinning solution and non-beaded fiber formation.

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FOOD PROCESSING: NANOTECHNOLOGY

THE EFFECTS OF VISCOSITY OF CHITOSAN-POLYVINYL ALCOHOL BLEND SOLUTIONS ON THE MORPHOLOGY OF NANOFIBERS WITH VITAMIN C

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ABSTRACT

The viscosity of a feed solution is one of the affecting factors during electrospinning. It influences the morphology of electrospun nanofibers, however, this effect is not always clear as the presence of other important factors. In this study chitosan (CS) and polyvinyl alcohol (PVA) were blended at various volume ratios to fabricate electrospun nanofibers with L-ascorbic acid. The purpose was to analyze the viscosity of various volume ratios of CS/PVA blend solutions and then determine the effect of solution rheology on the morphology of the nanofibers. The CS/PVA blend solutions were prepared at volume ratios of 10:90, 20:80, 25:75 and 50:50 and L-ascorbic acid was added to the solutions at 10 mg/ml. The viscosity measurements were performed using a rheometer (Haake Rheostress 1, Germany) equipped with the cone-plate sensor (C35/2, cone with d: 35 mm, angle: 2DEG; gap 0.105 mm) sensor at 25°C. The shear rate range was in between 0.01 and 200 s^{-1} in 120 s. The results were modeled using the software (Haake RheoWin3 Data Manager, Germany) according to the power-law equation. Results showed that all the solutions including pure CS, PVA and their blend solutions showed non-Newtonian (Pseudo plastic with n<1) behavior as the n values were lower than 1. Apparent viscosities depending on the determined maximum shear rate were 0.07 and 11.34 Pa.s for pure CS and PVA solution, respectively. Furthermore, apparent viscosities of blend solutions were 2.51, 0.93 and 0.51 Pa.s for 10:90, 25:75 and 50:50, respectively. According to the results, the viscosity of blend solutions decreased with increasing chitosan content from 10 to 50 due to the low concentration of CS solution (2% w/v) compared with PVA solution (12% w/v). These solutions then were electrospun and obtained nanofibers. The morphology and diameters of nanofibers will be determined. As a result, the outcomes of this study will help to analyze the effect of the viscosity of the feed solutions containing various polymers on the morphology of electrospun nanofibers with Vitamin C.

Keywords: *viscosity, chitosan, polyvinyl alcohol, nanofiber morphology*

TRADITIONAL FOODS/DRINKS

EFFECT OF SUGAR COMPONENTS ON SENSORIAL AND TEXTURAL PROPERTIES OF TURKISH DELIGHT (LOKUM)

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ABSTRACT

Sweets have always been an important component of Turkish cuisine. Lokum, Turkish delight, is a traditional confectionary in Anatolia since the 15th century and its production method has been developed to today's form at 19th century. It derives its name from the Ottoman word "rahat ul-hulkum" meaning "comforting to the throat". It is a jelly-like product manufactured by mixing sugar, corn starch and water with different seasonings, fruits and nuts and heating the mixture in an open vessels or steam jacketed tanks with agitator. Hot lokum fluid is dripped in wooden table or steel trays, refrigerated, sprinkled with starch or powdered sugar, and finally cut as small particles.

The most important quality parameter of lokum is its structural attributes such as softness and elasticity. There are very limited studies about lokum in literature, and there is no definite physical or textural attribute of lokum. However, it has been stated that lokum neither be too hard nor too soft. In addition, lokum should not be sticky which results in low chewiness.

The aim of the present work was to compare the impact of various sugar components (namely sucrose, glucose syrup and date syrup) on sensorial and textural properties of plain Turkish delight. The lokum samples were prepared using a commercial recipe (58% sucrose+35% water+7% corn starch or 93% glucose/date syrup+7% corn starch) in a local factory. The sensory analysis was performed by a total of 12 trained individuals immediately after the day of production. Based on the structure, hardness, taste, odour, colour, sweetness, resilience, gumminess and chewiness of the samples, the panellists were asked to score the samples on a hedonic scale of 1-5. Each sample was given a product code, the order was randomised and presented to the panelists on white plates. The sensory analysis was performed by a total of 12 trained individuals, especially selected on the basis of interest and experience, immediately after the day of production

Textural properties of lokum samples were evaluated on replicated samples with a texture analyser (TA-XT Plus, Stable Micro Systems, Godalming, Surrey, UK), using a two-bite compression of cylindrical samples of 36 mm of diameter. The parameters of hardness, adhesiveness, springiness, cohesiveness, gumminess, chewiness and resilience were calculated by the software of the device (Texture Exponent 32).

According to the sensorial analysis, lokum prepared with date syrup had the lowest scores for all the analysed parameters. The panelists stated that the lokum was too hard, had no elasticity and difficult to chew. Lokum samples prepared with sucrose and glucose syrup addition had similar scores. Texture profile analysis (TPA) showed that the lowest parameters were detected in sucrose added samples, whereas date syrup addition resulted in significant increase for all TPA parameters. The highest hardness value as 6805.838±790.049 g, with lowest springiness (0.711±0.0035) and resilience (0.081±0.0092) were for date syrup added being similar to sensory panel results.

Key Words: *Turkish delight, sugar components, texture, sensory properties*

TRADITIONAL FOODS/DRINKS

THE EFFECTS OF WHEY ADDING INTO COW, SHEEP AND GOAT MILK ON RHEOLOGICAL PROPERTIES OF KEFIR

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ABSTRACT

The effects of whey adding into milk on rheological properties of kefir was investigated. For this purpose, kefir samples were produced with cow's, sheep's and goat's milk and their mixture of whey (1:1 v/v). The rheological properties of the samples were determined using a rheometer. The shear ramp analysis consisted of up (from 0.01 to 300 s^{-1} in 120 s) and down (from 300 to 0.01 s^{-1} in 120 s) parts. The kefir samples were found to exhibit non-Newtonian behavior as pseudo-plastic for these kinds of milk. It was observed that an empirical power-law model was suitable to describe the rheological behavior of kefir samples produced from different kinds of milk with determination coefficients (R^2) of 0.99. The flow curves of the samples indicated thixotropic behavior, due to the fact that there was a hysteresis in up and down shear ramp application. The thixotropy was also confirmed from the apparent viscosity values as viscosities for the down ramp were lower than the viscosities for the up ramp. The apparent viscosity values of the kefir samples were between 13 (whey) and 315 (sheep's milk) mPa.s in up shear ramp and 7 (whey) and 221 (cow's milk) mPa.s in down shear ramp. For all samples, adding whey to formulations decreased the apparent viscosities especially for those samples used only cow milk and sheep milk. Flow behavior index (n) and consistency index (K) values for the kefir samples ranged from 0.22 to 0.92 (-), 0.01 to 10.88 $Pa.s^n$, respectively.

Keywords: *kefir, viscosity, whey*

INTRODUCTION

Whey, a major by-product of dairy industry remaining during the cheese-making is an important source of milk nutrient. The major nutrients of whey consist of lactose (approximately about 5%, w/v), soluble proteins (1% w/v) and minerals. Because of highly nutritious and high amount of producing, the utilization of whey is one of the main object of the studies [1]. For this purpose, kefir-like fermented beverages are one of the major food industrial utilization of whey because of high lactose content. Kefir is also naturally fermented dairy beverage with slightly acidic taste, yeasty flavor and creamy consistency [1-6]. Kefir is produced by inoculating with kefir grains or kefir starter culture [7]. Whey has a potential alternative source for beverage production since kefir microflora utilize lactose as an energy source and produce various degradation products [1, 4, 5]. The other biochemical reactions such as fat and protein degradations could have an effect on the quality parameters such as rheological and textural properties of kefir. In addition to the quality of kefir can be depended on the type of milk used for kefir production and microflora of kefir grains. The most consumers are not familiar to kefir texture, especially

consistency compared to drinking yogurt (ayran) that could be one of the principle parameter preventing the consumption of kefir. In this case, adding whey into milk using for kefir production must have provide a desirable rheological properties due to the lower consistency of whey compared to the milk. Some studies have been carried out the effect of different milk source such as mare's milk and its mixture with goat's and sheep's milk [8], sheep's milk [9], goat's and cow's milk [10] and using whey protein [11] on kefir chemical and physicochemical properties. However, the effects of whey adding directly into types of different milk (cow's, sheep's and goat's) on rheological properties of kefir are not known. Therefore, the object of this study was to evaluate of rheological properties of kefir produced with cow's, sheep's and goat's milk and their mixture with whey (1:1 v/v).

MATERIALS and METHODS

Materials

Kefir grains were provided from Ankara University, Department of Dairy Science (Ankara, Turkey). Cow's, sheep's and goat's milk was taken from the local producers (Hatay, Turkey). The whey (6.92% dry matter, 5% lactose) used for kefir production was obtained from the fresh goat milk cheese which made at Hatay Mustafa Kemal University, Food Engineering Department.

Methods

Kefir Production

The starter culture was produced using cow's milk by inoculating of kefir grains at 3% proportion. Cow's, sheep's and goat's milk, and whey were heated at 95°C for 5 min and after cooling, kefir starter culture was added into (3% v/v) each type of milk (cow's, sheep's and goat's milk) and their mixture of whey (1:1 v/v). Kefir was also produced with using whey, only. The samples were incubated at 25°C until pH 4.6 and then stored at 4°C.

Rheological Measurements

The viscosity measurements were performed using a rheometer (Haake Rheostress 1, Germany) using the plate-plate system (dia=35 mm, gap=1 mm) configuration at 22°C. The shear ramp analysis consisted of up (from 0.01 to 300 s^{-1} in 120 s) and down (from 300 to 0.01 s^{-1} in 120 s) parts. The measurements were performed twice for any given sample. The results were modeled using a software (Haake RheoWin3 Data Manager, Germany) according to the power-law equation:

$$\sigma = K\dot{\gamma}^n \quad (1)$$

where σ is the shear stress (Pa), $\dot{\gamma}$ is the shear rate (1/s), K is the consistency index (Pa.s^n) and n is the flow behavior index. The apparent viscosity, η (Pa.s), of the samples were calculated according to the equation given below:

$$\eta = K\dot{\gamma}^{n-1} \quad (2)$$

RESULTS and DISCUSSION

Rheological Measurements

The flow curves of kefir samples were given in Figures 1-4. The graphics were obtained the average values of two measurements for each sample.

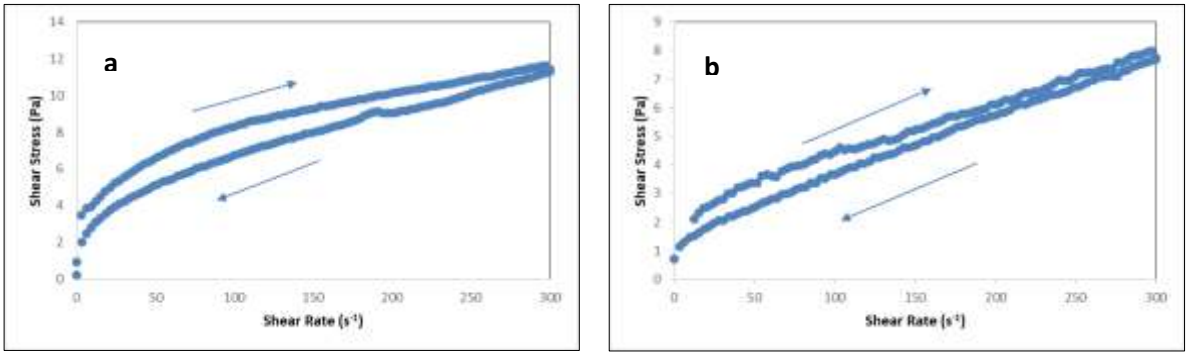

Figure 1. Flow curve of kefir with goat's milk (a) and goat's milk:whey (b)

All flow curves indicated thixotropic behavior, due to fact that there was a hysteresis in up and down shear ramp application.

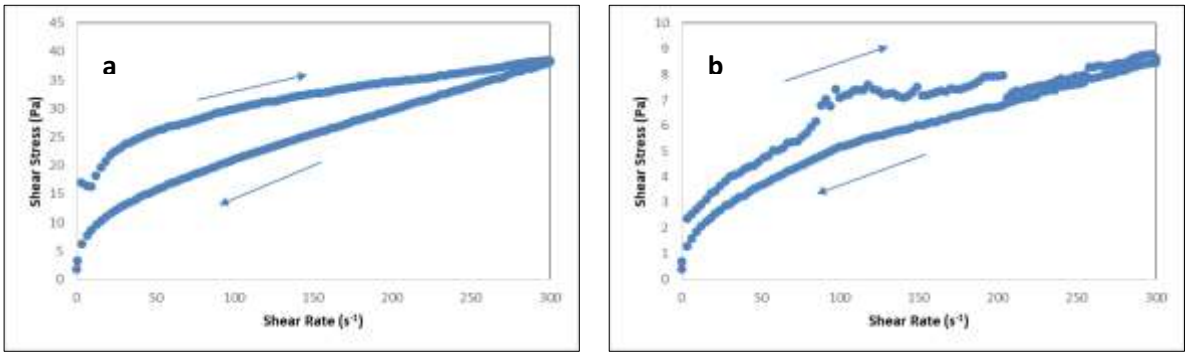

Figure 2. Flow curve of kefir with cow's milk (a) and cow's milk:whey (b)

The thixotropy was also confirmed from the apparent viscosity values given in Table 1, as viscosities for the down ramp were lower than the viscosities for the up ramp.

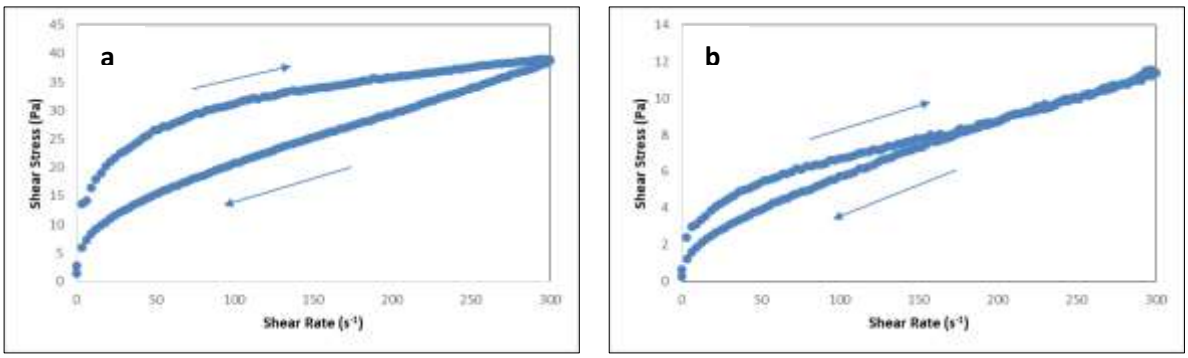

Figure 3. Flow curve of kefir with sheep's milk (a) and sheep's milk:whey (b)

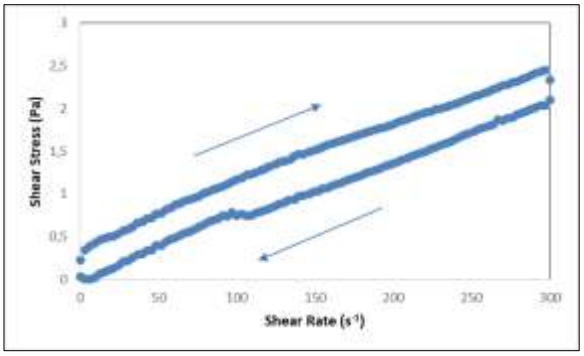

Figure 4. Flow curve of kefir produced with whey

K and *n* values of kefir samples were given in Table 1. As seen from the Table 1, all *n* values of samples were in between 0 and 1. This indicated that the rheological behavior of kefir samples was pseudoplastic. The calculated apparent viscosities at shear rate 100 s^{-1} according to the Eq (2) were also given in Table 1.

According to the studies conducted before, kefir samples with different variables/raw materials/ or produced by different methods had exhibited non-Newtonian behavior as pseudo-plastic as similar as founded in our study [3, 8, 10-14].

Table 1. K, n, R^2 and calculated apparent viscosity values of kefir samples

Sample	Milk Conc. (%, v/v)	Whey Conc. (%, v/v)	Shear ramp	K (Pa.s^n)	n	R^2	η_{100} (mPa.s)*
Cow's milk	100	0	Up	10.88±2.33	0.22±0.02	0.99	300
			Down	2.31±0.25	0.49±0.01	0.99	221
	50	50	Up	1.54±0.49	0.31±0.04	0.95	64
			Down	0.65±0.11	0.45±0.05	0.99	52
Sheep's milk	100	0	Up	10.43±1.88	0.24±0.01	0.99	315
			Down	2.07±0.06	0.50±0.01	0.99	207
	50	50	Up	1.09±0.12	0.40±0.03	0.99	69
			Down	0.40±0.09	0.59±0.05	0.99	61
Goat's milk	100	0	Up	2.00±0.05	0.31±0.00	0.99	83
			Down	0.96±0.06	0.43±0.01	0.99	70
	50	50	Up	0.53±0.04	0.47±0.02	0.99	46
			Down	0.23±0.03	0.61±0.04	0.99	38
Whey	0	100	Up	0.07±0.00	0.63±0.03	0.99	13
			Down	0.01±0.00	0.92±0.12	0.99	7

***** calculated at 100 s^{-1} by using Eq (2)

Tratnik et al. [10] fortified the cow's milk or goat's milk with 2% (w/w) skimmed milk, whey protein concentrate (WPC - 60g/100 g proteins, 3.1g /100g moisture) or inulin and fermented all milks with kefir grains. They reported that kefir samples produced using goat's milk had significantly lower viscosity values. Besides, the kefir samples supplemented with WPC had initially higher viscosities due to protein-water interactions, then viscosities decreased in course of time. All flow index (*n*) values in the study were being between 0 and 1 indicated that the rheological behavior of kefir samples fermented from cow's milk, goat's milk and milk supplemented with WPC was pseudoplastic as similar as founded in our study. Although, much protein content of WPC (60% protein of 97% dry matter) provided more water-binding capacity in their study, our whey (6.92% of dry matter, 5% lactose) could not bind much water

due to lower protein amount. Thus, much water content of whey and the less water-binding capacity may decrease the apparent viscosities for all samples supplemented with whey.

The decreases of the apparent viscosities of the samples were 79-76.5% for cow's milk, 78.1-70.5% for sheep's milk and 44.6-45.7% for goat's milk by adding whey for up and down shear ramps, respectively. Adding whey to goat's milk led less decrease because much protein content of goat's milk may provide more water-binding capacity than other milk types [10].

Similarly, Dimitreli et al. [11] investigated the effects of heat treatment and whey protein addition on the fermentation time and the rheological properties of kefir samples produced from homogenized bovine milk with and without the addition of WPC. According to the study, WPC addition increased the apparent viscosity of kefir samples. Furthermore, the addition of WPC to the milk followed by heat treatment resulted in kefir samples having a higher apparent viscosity compared with milk that was heated prior to the addition of WPC.

Ertekin and Guzel-Seydim [14] investigated the effect of fat-replacers on the flow type of non-fat kefir beverages produced from skim milk and whole milk. The researchers reported that kefir samples had non-Newtonian behavior and pseudoplastic fluid with thixotropy.

Kök-Taş et al. [3] investigated the effects of different fermentation parameters on quality characteristics of kefir. In the study, kefir samples were produced using kefir grains or natural kefir starter culture, and fermentation was carried out under normal or modified atmosphere (10% CO_2) conditions. The researchers reported that all kefir samples exhibited non-Newtonian pseudoplastic flow behavior according to the power law model.

Cais-Sokolińska et al. [8] produced kefir samples using mare milk with a mixture of goat and sheep milk and reported that kefirs made from a mixture of goat and sheep milk were firmer, had greater values of consistency and the viscosity index than those produced from mare's milk alone.

Ergin et al. [13] investigated the effect of homogenization of milk on rheological properties of kefir and revealed that at the end of the storage period viscosity, thixotropy and consistency coefficient values decreased due to the homogenization.

CONCLUSION

Kefir samples produced from cow's, sheep's and goat's milk and mixture with whey (1:1 v/v) of each milk type were evaluated. The rheological flow behavior of kefir samples exhibited a non-Newtonian thixotropic according to the flow index behavior values (n<1). Flow behavior index (n) and consistency index (K) values for the kefir samples ranged from 0.22 to 0.92 and 0.01 to 10.88 $Pa.s^n$, respectively. The thixotropy was also confirmed from the apparent viscosity values as viscosities for the down ramp were lower than the viscosities for the up ramp due to fact that there was a hysteresis in up and down shear ramp application. The apparent viscosity values of the kefir samples were between 13 (whey) and 315 (sheep's milk) mPa.s in up shear ramp and 7 (whey) and 221 (cow's milk) mPa.s in down shear ramp. For all samples, adding whey to formulations decreased the apparent viscosities especially for

those samples used only cow's and sheep's milk. The hysteresis loop areas of the curves correspond to the power necessary to break down the thixotropic structure of a given volume of solution.

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TRADITIONAL FOODS/DRINKS

RHEOLOGICAL PROPERTIES OF MILKS WITH SUCROSE OR LACTOSE TREATED WITH KOUMISS CULTURE

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ABSTRACT

Koumiss is a traditional fermented milk product containing 1–3% alcohol and mostly produced from mares' milk. The consumer's interest in kefir, koumiss and similar products due to the pieces of evidence of health benefits caused to develop the newer food-processing techniques. A few studies have been conducted so far, but homemade koumiss produce practising needs more research. Thus, we examined to produce a fermented beverage by adding koumiss culture to cow's milk and determine the rheological behaviour of the beverage by using a rheometer (Haake Rheostress 1, Germany). According to the results, our beverage exhibited non-Newtonian as thixotropic behavior (n<1) and the thixotropy was also confirmed from the apparent viscosity values as viscosities for the down ramp were lower than the viscosities for the up ramp. The apparent viscosity values of the samples were between 168 and 195 mPa.s in up shear ramp and 91 and 102 mPa.s in down shear ramp. Flow behavior index (n) and consistency index (K) values for the samples ranged from 0.12 to 0.60, 0.63 to 10.72 ($Pa.s^n$), respectively.Whereas adding lactose decreased the apparent viscosities for both ramps, adding sucrose increased viscosity for up ramp and decreased viscosity for down ramp. Consequently, adding different sugars did not cause any statistical significant difference between samples' viscosity values (p>0.05).

Keywords: *koumiss, dairy, viscosity*

INTRODUCTION

Koumiss (also known as koumyss, kumiss, kumys, kumyz, kimiz or coomys), is a traditional fermented milk product containing 1–3% alcohol and originating in the Central Asian steppes, especially in Tatars and Mongols, similar to kefir, mostly produced from mares' milk by spontaneous fermentation of lactose to lactic acid and alcohol [1-4]. This beverage is first mentioned in the 5th century BC as a preferred drink of the gods. Now, koumiss' and koumiss-like cow's milk products are consumed in from Caucasus region to Europe and North America [5, 6]. The composition of mares' milk is similar to human milk regarding its low nitrogen content, its low casein-to-whey protein ratio, its high content of lactose [3, 7, 8] (Table 1).

The consumer's interest in fermented milk products such as kefir and koumiss due to the pieces of evidence of health benefits caused to develop the newer food-processing techniques. The low availability (especially between November and June) and much cost of mare's milk to be used in the

production of koumiss dragged manufacturers and scientists to search for more suitable raw materials such as cow's milk. However, mare's milk content is significantly different from cow's milk [2, 6].

Table 1. Percentage contents of mare's, cow's and human's milk

	Contents of milk (%)					
	Water	Dry matter	Lactose	Fat	Protein	Ash
Mare milk	88.20	11.80	6.20	1.90	2.50	0.50
Cow milk	87.30	12.70	4.70	3.70	3.40	0.70
Human milk	87.60	12.40	7.00	4.00	0.90	0.20

Reference: Yilmaz and Kurdal [8]

High concentration of lactose in mare's milk (6%–7%) favors microbial fermentation, since it is decomposed by the starter cultures into lactic acid, ethyl alcohol, and other small molecules [2]. Therefore, membrane technologies have been used to modify cow's milk composition by decreasing protein amount and increasing lactose amount to simulate mares' milk and to produce koumiss. They have also used starter cultures consisting *Kluyveromyces lactis*, *Lactobacillus acidophilus* and *Lactobacillus delbrueckii* subsp*. Bulgaricus*. According to the chemical and sensorial analysis they have made, its reported that modified cow's milk can be used to produce koumiss [3, 9].

In our study, only carbohydrate content has been increased by adding lactose or sucrose to modify cow's milk for a proper fermentation process like mare's milk. The aims of the study were two folds: the first one was to produce a homemade beverage by using koumiss culture and cow's milk, the second one was to observe the rheological behaviour of the beverage.

MATERIALS and METHODS

Materials

Koumiss culture, sucrose and cow's milk were purchased from a local store. Lactose was purchased from Merck, Germany.

Sample Production

Production was made according to the formula of the koumiss culture producer company. Firstly, the sugars were added to the cow's milk with same amount (2.5% w/w = 6.25g sugar/200g cow's milk) as shown in Table 2. After dissolving sugars in milks by hand shake, 0.1 g koumis grains were added to each cow's milk bottle. Then the samples were incubated 24 hours at 30^{o}C.

Table 2. Dairy materials used for producing kefir samples

Sample	Added sugar type
N	Non-added
S	Sucrose
L	Lactose

Methods

Rheological Measurements

The viscosity measurements were performed using a rheometer (Haake Rheostress 1, Germany) using the plate-plate system (dia=35 mm, gap=1 mm) configuration at 22°C. The shear ramp analysis

consisted of up (from 0.01 to 300 s^{-1} in 120 s) and down (from 300 to 0.01 s^{-1} in 120 s) parts. The measurements were performed twice for any given sample. The results were modeled using a software (Haake RheoWin3 Data Manager, Germany) according to the power-law equation:

$$\sigma = K\dot{\gamma}^n \quad (1)$$

where σ is the shear stress (Pa), $\dot{\gamma}$ is the shear rate (1/s), K is the consistency index (Pa.s^n) and n is the flow behavior index. The apparent viscosity, η (Pa.s), of the samples were calculated according to the equation given below:

$$\eta = K\dot{\gamma}^{n-1} \quad (2)$$

Statistical Analysis

All experiments and measurements were carried out in dupplicate. Experimental data were subjected to analysis of variance (ANOVA) by using SPSS 22.0 (IBM, NY, USA).

RESULTS

Rheological Measurements

The flow curves of koumis culture added milk samples were given in Figures 1. The graphics were obtained the average values of two measurements for each sample. All flow curves indicated thixotropic behavior, due to fact that there was a hysteresis in up and down shear ramp application.

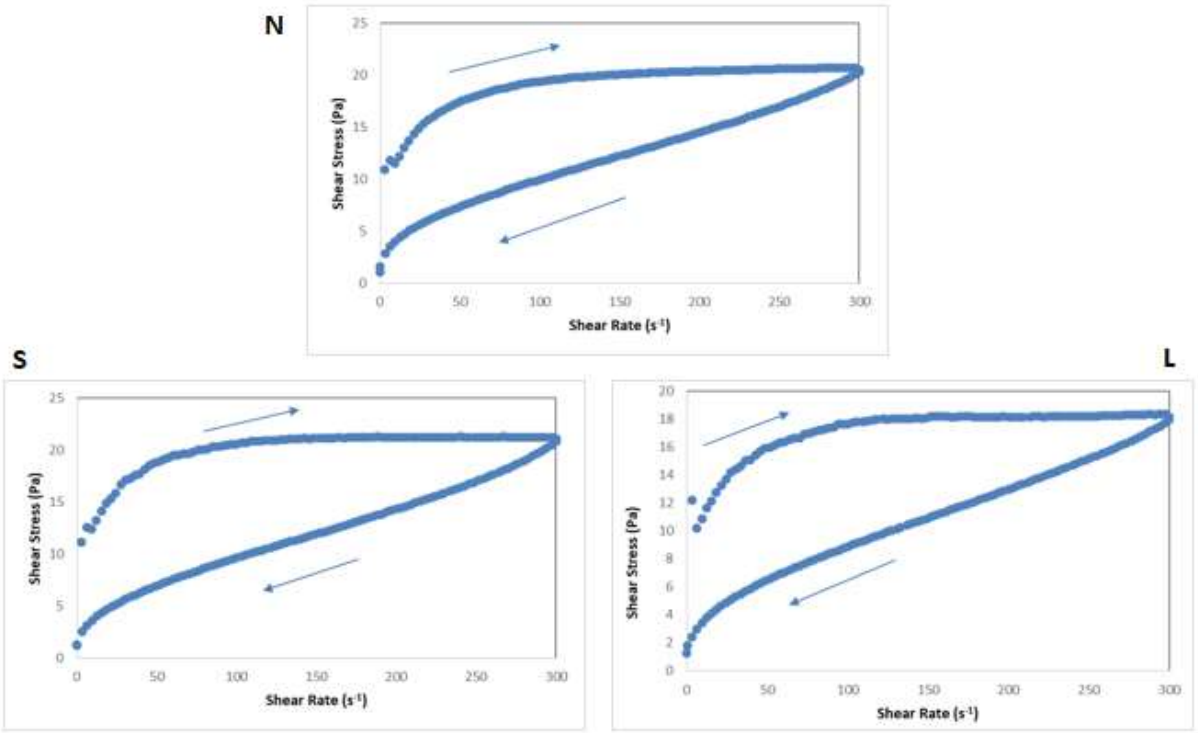

Figure 1. Flow curves of non-added cow's milk sample (N); sucrose added milk sample (S); and lactose added milk sample (L)

The thixotropy was also confirmed from the apparent viscosity values given in Table 3, as viscosities for the down ramp were lower than the viscosities for the up ramp.

According to the studies conducted before, koumiss culture added different milk samples had exhibited non-Newtonian behaviour as pseudo-plastic [5, 10, 11]. Besides, our final products had shiny appearances, smooth texture, and custard-like consistency as similar to yogurt's rheological characteristics due to the coagulation of milk proteins and formation of yogurt like appearance [12]. However, they did not have a gel-like viscoelastic structure like yogurt [13]. The flow behavior index values were between 0 and 1 which means the structure had non-Newtonian behaviour. Tamjidi et al. [14] determined the consistency index values of yogurt samples between 15.31-17.76 $Pa.s^n$ which were higher than that of our consistency index values and revealed yogurt samples' flow behaviour as non-Newtonian shear-thinning. The apparent viscosity values were much higher than that of founded before on koumiss samples produced from cow's milk [3, 5].

Table 3. K, n, R^2 and calculated apparent viscosity values of samples

Sample	Shear ramp	K ($Pa.s^n$)	n	R^2	η_{100} (mPa.s)*
N	Up	9.59±0.49	0.14±0.01	0.95	186
	Down	0.82±0.02	0.55±0.01	0.99	102
S	Up	10.72±0.85	0.13±0.01	0.92	195
	Down	0.63±0.01	0.60±0.00	0.99	98
L	Up	9.59±0.59	0.12±0.01	0.93	168
	down	0.71±0.01	0.55±0.00	0.99	91

***** calculated at 100 s^{-1} by using Eq (2)

Moreover using lactose favored the lactic acid fermentation process resulted in more acidity in the media which led a decrease of apparent viscosity of the sample due to the denaturation of water-binding proteins [15]. On the other hand, it is thought that since the decomposition of sucrose was not favored by koumiss grains (lactic acid bacteria) enough, the apparent viscosity of sucrose added sample was higher than that of other samples [2].

Di Cagno et al. [5] manufactured fermented milks by using mare's, cow's and sheep's milk fortified with sodium (Na)-caseinate, pectin, sucrose and/or threonine. All fermented milks produced in the study had exhibited non-Newtonian pseudo-plastic behaviour according to the flow behaviour index values (*n*=0.27-0.70).

Küçükçetin et al. [3] have adaptated the bovine milk towards mares's milk composition to produce koumiss by using membrane technologies. After adaptation procedures, they revealed that the mean values of apparent viscosity of koumiss made from the modified cow's milk (6.9±0.2 mPa s) were higher than that from koumiss made from the mares' milk (6.1±0.1 mPa s). Besides, the density values of both koumiss samples were equal. On the other hand, the apparent viscosity values were very lower than our results. That's probably because they have simulated milk formulas by using membrane technologies.

Özer and Kirmaci [10] also revealed that traditional koumiss production requires some modifications due to the limited availability of mare's milk. However mare's milk's low level of casein compared to cow's milk resulting no coagulation of fermentate. Thus, they suggested to dilute milk with water, then add whey or whey protein concentrate and sugar [2.5 g sugar (glucose, sucrose or lactose)/100 g milk] to simulate mare's milk content. Another altenative way they have suggested is to benefit of membrane technologies after some modification of content as Küçükçetin et al. [3] have recommended before.

Sabancı et al. [11] investigated the rheological properties of koumiss depended on the effects of temperature on time and revealed that their shear stress–shear rate data experiments were fitted to different rheological models. According to the power-law model, koumiss samples exhibited shear thinning (n<1) flow characteristic with similar flow behavior indexes for the temperature range studied. The effect of temperature which was assessed by Arrhenius equation showed that koumiss samples also exhibited the time dependent thixotropic behavior as similar as founded in our experiment. The researchers also showed and calculated the hysteresis loop area between up and down ramp curves and revealed that this area has the dimensions of power per unit volume ($Pa.s^{-1}$) and corresponds to the power necessary to break down the thixotropic structure of a given volume of solution [16].

CONCLUSION

Modifying cow's milk by just adding sugars is not enough to produce a koumiss-like beverage. Not only sugar content but also protein content should be modificated as reported before. Moreover using lactose favored the lactic acid fermentation process resulted in more acidity in the media which led a decrease of apparent viscosity of the sample due to the denaturation of water-binding proteins. On the other hand, since the decomposition of sucrose was not favored by koumiss grains enough, the apparent viscosity of sucrose added sample was higher than that of other samples.

Although, milks treated with koumiss culture turned into yogurt-like product, rheological behaviour of the samples seem to be koumiss' flow behaviour as non-Newtonian thixotropic according to the flow index behaviour values (n<1). Flow behavior index (n) and consistency index (K) values for the samples ranged from 0.12 to 0.60 and 0.63 to 10.72 ($Pa.s^n$), respectively. The thixotropy was also confirmed from the apparent viscosity values and the flow curves, due to fact that there was a hysteresis in up and down shear ramp application. The apparent viscosity values of the samples were between 168 and 195 mPa.s in up shear ramp and 91 and 102 mPa.s in down shear ramp. The hysteresis loop areas of the curves correspond to the power necessary to break down the thixotropic structure of a given volume of solution.

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ORAL PRESENTATIONS FROM COMPANIES

Parçacık Özellikleri, Reoloji ve Stabilite İlişkisi

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ÖZET

Bir dispersiyonun stabilitesi, dispers fazın sürekli faz içinde askıda kalarak sedimantasyona veya kremalaşmaya (akışa) ne kadar direnç gösterebildiğiyle ilgilidir. Kolloidal bir sistemin dengesini dispers partikülleri veya damlacıkları etkileyen yerçekimi ve Brownian kuvvetleri belirlemektedir. Mikron-altı parçacıklarda yerçekimi etkisi baskın değilken, parçacıkların boyutları büyüdükçe ve mikron üzerine çıkıldıkça yerçekimi etkisi Brownian etkisine baskın gelmektedir. Belirli bir süre sonunda gözle görülür sedimantasyon ve en nihayetinde faz ayrılması kaçınılmaz hale gelmektedir.

$$V = \frac{\Delta\rho g a^2}{18\eta}$$

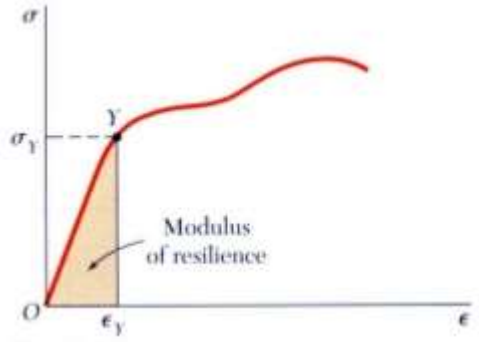
Yerçekimi Kuvveti $\longrightarrow$ $a^4 \Delta\rho g$

Brownian Kuvveti $\longrightarrow$ $k_B T$

Seyreltik sistemlerin terminal hızı (V) yukarıdaki ifadede görüldüğü üzere fazlar arasındaki özgül ağırlık farkı ($\Delta\rho$) parçacık çapının (a) karesi ve yerçekimi katsayısı (g) ile doğru orantılı, viskozite (η) ile ters orantılıdır. Parçacıkların veya damlacıkların boyutunu ve fazlar arası özgül ağırlık farkını azaltamak ve/veya sistemin viskozitesini arttırmak sedimantasyon veya kremalaşma hızını azaltacak dolayısıyla stabiliteyi arttıracaktır.

Reolojik açıdan bakıldığında düşük kayma hızlarında veya düşük frekanslı osilasyonda yani dinlenir haldeyken sistemin viskozitesinin ve faz açısının ölçümü stabiliteyi belirlemeyi sağlamaktadır. Bu bilgi düşük kayma hızları ve küçük gerilim değerleri altında hassas viskozite ve faz açısı ölçümleri yapabilen reometreler ile sağlanabilmektedir. Diğer yandan bu reometreler ile yapılabilen osilasyon testleri sayesinde sistem mikroyapısının deformasyona karşı bozulmadan ne kadar elastik enerji soğurarak dayanabileceğini gösteren kohezif enerjinin ölçümü gerçekleştirilebilmektedir.

Malzeme biliminde katı malzemelerin karakterizasyonunda kohezif enerji yerine gerinme (strain) enerjisi veya derlenme modülü (modulus of resilience) terimleri de kullanılmaktadır. Malzeme bilimcileri strain-stress grafiğinde lineer artışın kesildiği yere kadar olan kısmın integral alanını bu terimi ifade etmekte kullanırlar (Şekil 1).



Şekil 1. Doğrusal viskoelastik bölge (LVER) ve kohezif enerjinin stress-strain grafiği ile gösterimi

Anahtar kelimeler: *dispersiyon stabilitesi, sedimantasyon, kremalaşma, faz ayrımı, kohezif enerji, elastik enerji, gerinme enerjisi*

ORAL PRESENTATIONS FROM COMPANIES

Gıdalarda Tekstür ve Reoloji Uygulamaları

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ABSTRACT

The Brookfield brand has been considered the world standard in viscosity measurement and control of liquids and semi-solids for more than 80 years. Our CT-3 Texture Analyzer has also gained a reputation for being the ideal tool for tension and compression testing. And our Powder Flow Tester is fast becoming the favorite for its quick and easy analysis of powder flow behavior in industrial processing equipment. We have an excellent global support system in regional offices and a network of training representatives and dealers. No wonder research labs, QC and production environments count on Brookfield's reliable instrumentation for dependability and accuracy.

Anahtar kelimeler: *Brookfield viscometer, CT3 texture analyzer, PFT*

ORAL PRESENTATIONS FROM COMPANIES

How Rheology Can Proactively Prevent Daily Chocolate Production Problems

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ABSTRACT

Our lovely sweet snack chocolate is found in different forms like a solid tablet or enrobed bar or dragee, etc. in the market. Chocolate mass is subject to different speeds in the above mentioned forming machines, from very low speeds to reasonably high speeds. Since chocolate is a non-Newtonian fluid, measuring and understanding its rheology and adjusting it to different processing equipment is extremely important to prevent problems during production. The choice of a right viscometer/rheometer, using an informative measurement method and evaluating the results for preventive actions are key in chocolate manufacturing. This presentation aims to show how rheology science helps to relate the results of a viscosity measurement to different chocolate processing machines in the real daily life and how by using different emulsifiers to adjust the chocolate rheology for different applications.

Keywords: *rheology, chocolate, viscosity*

POSTER PRESENTATIONS

EFFECT OF SPROUTED WHEAT FLOUR ON LAOS PROPERTIES OF WHEAT FLOUR-WATER DOUGH

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ABSTRACT

Composition of food materials plays significant roles in the structure, physicochemical stability and nutrition. Classical rheological methods are inadequate to characterize and to differentiate the non-linear rheological behavior of food material which is complex multiphase systems like bread dough. Large Amplitude Oscillatory Shear (LAOS) testing has been carried out in rheological analyses of food system. LAOS tests can quantify viscoelastic moduli under high deformations. The goal of this study is to investigate LAOS behaviours for wheat flour-water dough (WD) and 30% sprouted wheat flour added dough (SWD). LAOS parameters (e_3/e_1 , v_3/v_1 , *S* and *T*) were used to figure out the structural changes in these products at 10 rad/s and strain in the ranges of 0.01-200 at 25°C. Strain hardening and shear thinning were observed (positive values of e_3/e_1 and negatives values of v_3/v_1) for WD. On the other hand, SWD indicated structural change in strain hardening (positive values in e_3/e_1) and shear thinning (negative values in v_3/v_1) in the small oscillatory region, e_3/e_1 values began to decrease from the mid oscillatory region followed by strain softening (negative values in e_3/e_1) in the large oscillatory region. Both the storage modulus (G') and the loss modulus (G''), showed a dramatical decline at the entrance of the LAOS region for SWD. The crossover strain points of G' and G'' for WD and SWD were 50.1% and 31.6%. *S* values of WD and SWD were 1.33 and 0.76 and *T* values of WD and SWD were 0.68 and 0.64 at 200% of strain, respectively. *S* and *T* values were lower for SWD due to high levels of hydrolytic enzymes (proteases) during sprouting. LAOS data can be useful for creating functional flour blends to produce high quality bread.

Key Words: *LAOS, non-linear rheology, dough, sprouted wheat*

INVESTIGATION OF LAOS BEHAVIOR OF XANTHAN AND LOCUST BEAN GUM

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ABSTRACT

In the food industry hydrocolloids are often used as stabilizers, viscosity enhancers and gelling agents etc. in wide range of food types to improve quality of the end products. Their responses against to applied forces during production, transportation, shelf life and consumption influence acceptability of the food products. Those materials used in products are exposed to large deformations and it can change their effect on final product. Purpose of this study is to investigate the rheological behaviour of xanthan gum (XSG), locust bean gum (LBG) solutions and their mixtures at different concentration levels within nonlinear region.

First of all, 0.1%, 0.3% and 0.5% xanthan gum (XSG) and locust bean gum (LBG) stock solutions were prepared. Mixture solutions were prepared using these solutions in a ratio of 2:3 with three different way. One of the mixtures were prepared immediately (HB), one were prepared after 24 h (HA) and one of them were in powder form without changing the ratio (P). Rheological measurements were performed using a Rheoplus LAOS module (Anton Paar, MCR-302) attached with a 50 mm parallel plate system at 1 mm gap and 25°C and between 0.005 and 500% strain values at 10 rad/s frequency.

As a result of LAOS analysis, Lissajous-Bowditch curves were drawn and investigated. According to the curves, elasticity component of the samples were became more elliptical as the strain values increased. As expected, viscous component of the samples were became more circle and area of the circle increased with strain values. At 500% strain value, elastic component of P sample had more elliptical curve than those of HB and HA samples at all concentration levels but more observable at 0.3%. According to those observations it can be stated that P sample is more stable than HB and HA samples against deformation in terms of elastic structure.

Key Words: *LAOS, non-linear region, xanthan gum, locust bean gum*

DETERMINATION OF DEFORMATION AND RECOVERY PROPERTIES OF CAMELINA (*Camelina sativa*) SEED GUM SOLUTIONS AT DIFFERENT CONCENTRATION LEVEL USING THREE INTERVAL THIXOTROPY TEST (3ITT)

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ABSTRACT

3ITT means three interval thixotropy test which consists of three intervals. This test gives information about degree of recovery after deformation is applied. In the present study, the percentages of deformation and recovery were determined and the percentage of deformation for the storage modulus (G') and loss modulus (G'') ranged from (50.49-54.91%) and (73.76- 82.28%) at 0.6, 0.8, 1, 1.5 and 2% w/v, respectively. Moreover, regarding storage modulus (G') and loss modulus (G'') the percentage of recovery ranged from (84.86-92.87%) and (80.34-100%) at different concentration levels, respectively. Besides, second order structural model was applied to the third interval. As R^2 values of gum solutions were higher than 0.96, this model was fitted well with acquired datas. In addition, *K'* and *K"* values of the solutions were found in the range of 0.0112-0.0129 Pa and 0.0045-0.0143 Pa, respectively. The *K"* value of 0.6% solution was larger than the *K'* value, suggesting that it exhibited viscous property. In contrast, the *K'* values of the solutions were larger than the *K"* values, their elastic behaviours were more dominant than viscous behaviour at other concentration levels larger than 0.6%.

Key words: *3ITT, Camelina seed gum, concentration, deformation, recocery*

STEADY SHEAR RHEOLOGICAL PROPERTIES OF GUM EXTRACTED FROM ACACIA SEEDS

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ABSTRACT

Gums are complex polysaccharides which are highly soluble in water, for that reason they are extracted from plant exudates or plant seeds easily. They are widely used in the food industry as stabilizers, suspending agents, thickeners, emulsifiers, fat replacer, plasticizing, binding and gelling agent, moreover they are utilized as encapsulating coating material. There are many sources for gum production as plants and microorganisms, among these sources acacia trees are one of prominent plant source. Composition and characteristics of acacia gum changed according to enviromental conditions and intrinsic factors. In this study, Acacia seed gum was extracted from the seed coat of *Robinia pseudoacacia*. Extraction yield of Acacia gum was obtained as 4.38%. Gum solutions were prepared which had concentrations of 0.25, 0.5 and 1%. All rheological parameters were significantly affected from concentrations of gum solutions. Gum solutions with 0.5 and %1 had shear-thinning behavior while 0.25% concentration showed Newtonian fluid behavior. Ostwald de Waele model well described the flow behaviour of 0.5 and 1% gum solutions. Consistency coefficient, flow behaviour index and R^2 values were found as 0.110 and 1.452 Pa.s^n; 0.895 and 0.734; and 0.994 and 0.975, respectively for 0.5 and 1% gum concentrations. Viscosity of 0.25% gum solution was found to be 0.013 Pa.s. It can be concluded that; based on the obtained data Acacia seed gum can be used for modification of rheological characteristics of various food groups to improve quality of the food products in terms of many aspects.

Key Words: *Acacia seed gum, steady shear rheology, concentration*

EFFECT OF CONCENTRATION ON VISCOELASTIC PROPERTIES OF *Camelina sativa* SEED GUM SOLUTIONS

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ABSTRACT

The viscoelastic properties of Camelina seed gum (CSG) were determined using frequency sweep test which was performed at %1 strain (within LVR) (0.6, 0.8, 1, 1.5 and 2% w/v). The G' and G'' values of all concentration level increased with increase in angular frequency (ω). Moreover, the viscoelastic behaviour of the camelina gums solutions was predominantly elastic over the range of angular frequencies for 0.8, 1, 1.5 and 2% w /v concentrations, indicating that the G' values were predominant than G'' over the frequency domain. On the other hand, the G'' value was higher than G' value at 0.6% w/v concentration, suggesting that the gum solution exhibited a viscous-like behaviour. Power law model was fitted satisfactorily to obtained results (R^2>0.97) and found that the *K′* and *K″* values were in the range of 0.0041-10.6006 and 0.0160-2.5474 Pa, respectively. Besides, *n′* and *n″* values of tested samples were in the range of 0.2457-2.2087 and 0.0160-2.5474, respectively.

Key Words: *Camelina seed gum, concentration, viscoelastic behavior*

SYNERGISTIC INTERACTION OF XANTHAN, GUAR AND LOCUST BEAN GUM INVESTIGATED BY VISCOSITY

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ABSTRACT

Polysaccharides are extensively used in food formulations due to their functionality such as thickening, gelling and emulsifying. Xanthan interacts with galactomannans to form mixed gels, thus the viscosity of these polymer is increased synergistically even at low total polysaccharide concentration. In this study, described herein the increasing of viscosity with respect to their synergistic interaction, of a mixture of xanthan, guar and locust bean gum. Various solutions of xanthan, guar and locust bean gum having a total solid concentration of 0.5% (w/v) were prepared. The viscosity of solutions was measured using rotational viscometer. Results showed that solutions made using xanthan gum were higher viscosities than others in individual solutions. In addition, mixtures of xanthan gum and locust bean gum solutions showed higher synergistic effect than mixtures of xanthan and guar gum. The highest viscosity was obtained for the solution mixture at xanthan, guar and locust bean gum ratio of 3:1:1 (w/v). The viscosity of xanthan gum is 2900 cP, whereas it combined with guar and locust bean gum, the viscosity of solutions rise to 88000 cP, approximately. The viscosity of gum mixture has provided 30-fold increase as a conclusion of strong interaction occurred between xanthan, guar and locust bean gum.

Key Words: *viscosity, guar gum, xanthan gum, locust bean gum*

INTRODUCTION

Xanthan gum is a non-linear anionic microbial polysaccharide synthesized by aerobic fermentation of *Xanthomonas campestris*. It can be form highly viscous solutions even at low concentrations and stability of the solutions is not affected by temperature or pH. Therefore, xanthan finds great applications in the food industry, pharmaceutical and also cosmetics [1]. Xanthan gum composed of a 1-4-linked β-D-glucose backbone substituted with a trisaccharide side chain. When these side chains bind to the helical backbone, helical structure stabilized, and rather stiff rod formed with great stability to heat, acid, and alkali. Thus, xanthan gum solutions gain greater viscosity and pseudoplasticity because of the formation of high-molecular-weight aggregates of stiff rod molecules [2, 3].

Xanthan can interact with galactomannan to form mixtures of high viscosity and gel formation even at low polysaccharide concentrations and this property is exploited in food applications in which thickening or gelling is desired. The synergistic interaction between xanthan and galactomannans was first mentioned by Rocks [4]. The main differences for xanthan and galactomannan interactions can be explained by the molecular xanthan conformation and the galactomannan structure in gum solution. The structure of xanthan can change with the temperature of solution. At low dissolution temperatures,

xanthan shows an ordered conformation, hovewer at higher temperatures xanthan shows a disordered structure [2, 5].

Galactomannans are polysaccharides and mainly natural sources of galactomannans are coffee beans, soy beans, alfalfa seeds, pineapple, sugar beets, and locust beans which are mostly used in the food industry as thickening agents, fire-extinguisher and agricultural applications [6, 7]. Galactomannan main chain is composed of a 1-4 linked β-(D)-mannose backbone which may be substituted by a α-(D)-galactose side units. Commercially available galactomannans are locust bean gum (LBG), tara gum and guar gum. Typically, the mannose/galactose (M/G) ratios for these gums are 3.55, 3.0 and 1.56, respectively. This ratio can change depending on temperature [1, 3].

Guar gum is a galactomannan obtained from the endosperm of the *Cyamopsis tetragonolobus* seed. The principal backbone is a chain of (1–4)-β-D-mannopyranosyl units, with single (1–6)-α-D galactopyranosyl units linked to the main chain [7]. The interactions among galactomannan molecules, with other galactomannans or with other polysaccharides, are enhanced by the presence of smooth regions. The average molecular weight of guar gum can vary from 440 to 650 KDa, depending on the polysaccharide chain-length. Dilute solution of guar gum (less than 1%) behaves as Newtonian system, whereas the concentration reached the higher amounts guar solutions behave as shear-thinning and thixotropic behavior which means viscosity reduced with increasing shear rate. Guar gum is used as a thickening agent mainly in the food, textile and paper industries. The main characteristic feature of guar gum is easily to hydrate in cold water to give highly viscous solutions [5, 8].

LBG or also called carob gum is obtained from endosperm of the seed of the carob tree (Ceratonia siliqua). This gum increases significantly the viscosity of the solutions, however it is only slightly soluble in cold water and to achieve full viscosity potential, LBG must be heated to about 80°C. LBG is used as a thickener, especially in the food, pharmaceutical and cosmetic industries. LBG is a galactomannan with a principal backbone (1-4) linked to a β-D-mannopyranosyl unit having side stubs of (1-6)-linked α-D-galactopyranosyl groups. The molecular weight of this polysaccharide is between 300 and 360 KDa [2, 6].

The non-gelling agents (xanthan and guar gum), and gelling agents (carrageenan and LBG) are generally combined together to obtain higher viscosity or greater properties of food gels. Researchers showed the importance of using gum mixture in food industry for the development of synergistic mixtures with improved or induced gelation. Ramirez et al. [1] reported that using of xanthan and LBG alone were not appropriated to be employed as surimi additive. However, these gums presented a beneficial effect when used at xanthan/LBG ratio 1/3. Studies proofed that the mixture of different polysaccharides provides an alternative way to the development of new textures. In this study, investigation of the synergistic interaction of gum mixtures, xanthan, guar and LBG, on viscosity were aimed and different gum ratio was employed to determine the its effects on viscosity.

MATERIALS and METHODS

Materials and Preparation of Gum Solutions

Guar gum, LBG and xanthan gum were supplied by INCOM Ltd. Sti. (Mersin, Turkey). The different proportions of gum solutions were prepared by mixing totally 0.75 g gum and 150 mL distilled water while continuously stirring at ambient temperature. The solutions were heated for 30 min at 80°C with stirring at 300 rpm, then were cooled to ambient temperature and immediately viscosity of solutions measured. Full factorial design were prepared to study the gum interactions affected the viscosity, xanthan/LBG/guar ratios have been employed shown in Table 1.

Table 1. Xanthan, guar and LBG ratios in solutions

	Concentration (%)				Concentration (%)		
Samples	Xanthan	LBG	Guar	Samples	Xanthan	LBG	Guar
Sample set 1	0.5	-	-	Sample set 12	-	0.1	0.4
Sample set 2	-	0.5	-	Sample set 13	-	0.2	0.3
Sample set 3	-	-	0.5	Sample set 14	-	0.3	0.2
Sample set 4	0.1	-	0.4	Sample set 15	-	0.4	0.1
Sample set 5	0.2	-	0.3	Sample set 16	0.1	0.1	0.3
Sample set 6	0.3	-	0.2	Sample set 17	0.1	0.2	0.2
Sample set 7	0.4	-	0.1	Sample set 18	0.1	0.3	0.1
Sample set 8	0.1	0.4	-	Sample set 19	0.2	0.1	0.2
Sample set 9	0.2	0.3	-	Sample set 20	0.2	0.2	0.1
Sample set 10	0.3	0.2	-	Sample set 21	0.3	0.1	0.1
Sample set 11	0.4	0.1	-				

Viscosity Determination

Viscosity measurements of gum solutions were carried out using a rotational viscometer (HAAKE Viscotester 6L/R Plus) which measuring the viscosity based on the principle of the force applied to overcome the resistance against rotation or flow. Spindle L1, L2, L3 and L4 were used according to the viscosity of gum solutions and power (%), speed (rpm) and viscosity (cP) were measured at given conditions.

Statistical Analysis

Experiments and analyses were carried out in dublicate. Data were subjected to one-way analysis of variance (ANOVA). Means were compared by Tukey's test at a significance level of 0.05 using statistic program Minitab 16 (Minitab Inc, Coventry, UK).

RESULTS and DISCUSSION

The Viscosity of Gum Solutions

Before investigation of xanthan, guar and LBG mixtures, we paid attention to the viscosity of each polysaccharide alone in solution. Xanthan gum showed 14 and 25-fold higher viscosity than guar and LBG solutions, respectively. Table 2 shows how the viscosity of two and three combination of gums vary with respect to polysaccharide ratio, which spindle was used and applied power during viscosity measurement.

Viscosity of Mixtures of Xanthan/LBG, Xanthan/Guar Gum and Guar Gum/LBG Solutions

The viscosity values of xanthan/LBG mixture were found different at given ratios. These results suggest an intermolecular synergism between xanthan and LBG, which was greater at ratio of 1:4 (w/v), as can be seen in Table 2. Casas et al. [6] also reported that mixtures of xanthan/LBG with the highest viscosity are reached at the highest LBG dissolution temperature studied at 80°C. Sandolo et al. [9] showed the synergistic interaction between LBG and xanthan mixture, and this mixture can be used in emulsions to remain samples longer uniform and reduced liquid separation [10].

Mixtures of xanthan and guar gum solutions have higher viscosities than that of each separate gum solution. The rheological behavior of these mixture is pseudoplastic and hereby the viscosity of these solutions changes with shear rate [5]. The viscosity of xanthan/guar mixtures changes, at a fixed polymer concentration, depending on the ratio between xanthan and guar gum concentrations. Viscosity has increased from 1515 cP to 18115 cP when xanthan/guar gum ratio changed from 1:4 to 2:3 (w/v).

The viscosity of xanthan/LBG solution mixture is higher than that of xanthan/guar gum mixture. Galactomannans have many hairy zones, galactose units linked regularly to mannose chain. The hot water-soluble fraction of LBG has a lower galactose content, where many smooth regions can be found. Smooth regions show very strong interactions with xanthan molecules [6]. Regarding the effect of the galactomannan which have less substituted, Cheetham and Mashimba [11] clearly proved the synergistic interactions of xanthan and LBG (M/G~3.5) than for guar gum (M/G~1.5). Renou et al. [3] also explained the xanthan and LBG interactions with *G'* of the mixture of gums was about 3 times greater than xanthan, this enhancement is clearly related with the interactions.

The viscosity of guar gum solution is greater than that of LBG solution. Guar gum has a higher molecular weight than LBG and, therefore, its solution shows a higher viscosity than LBG. LBG/guar gum mixture showed lowest viscosity compared to other gum combinations. If the ratio of guar gum was higher than LBG in mixture, the viscosity of mixture showed similar trend to guar gum, in the same way if LBG ratio was higher than guar gum in the mixture, the viscosity of solution showed similar trend with LBG. Therefore, these results showed us there was no interaction between two galactomannans, LBG and guar gum.

Viscosity of Mixtures Xanthan/LBG/Guar Gum Solution

To evaluate the synergistic effect of gum mixtures, all mixtures were dispersed in solution at the same total number of mixed polysaccharides in solutions of 0.5% (w/v). For a given total gum concentration, different gum ratio of three gum was investigated. The interaction between these gums depend on ratio, the highest viscosities have been achieved when a xanthan/LBG/guar gum ratio of 3:1:1 and 1:2:2 (w/v) is used. When guar gum was higher ratio in the mixture, the viscosity of solution showed lowest value compared to other xanthan/LBG/guar gum mixtures. The viscosity of xanthan and LBG mixture with a ratio of 3:2 (w/v) showed 61640 cP, when guar gum added with the same amount of LBG the viscosity of xanthan/LBG/guar gum with a ratio of 3:1:1 (w/v) showed 1.4 times higher viscosity (Table 2). Likewise, these results showed an intermolecular synergism between xanthan/LBG/guar gum (1:2:2), which was 57 times greater than xanthan/guar gum mixture at a ratio of 1:4 (w/v).

Table 2. Viscosity of xanthan, guar and LBG and their mixed solution

Gum ratio in mixture	Spindle	Power (%)	Viscosity (cP)*
Xanthan (0.5%)	L2	48.4±0.8	2901.5±47.4^{hi}
LBG (0.5%)	L2	18.9±0.4	113.5±2.1^{i}
Guar Gum (0.5%)	L2	33.7±2.7	202.5±16.3^{i}
1:4 (Xanthan:Guar)	L3	63.1±6.8	1515.0±162.6^{hi}
2:3 (Xanthan:Guar)	L3	67.4±3.6	18115.0±1887.9^{gh}
3:2 (Xanthan:Guar)	L4	11.5±0.8	13805.0±983.9^{hi}
4:1 (Xanthan:Guar)	L4	9.0±1.9	10700.0±2078.9^{hi}
1:4 (Xanthan:LBG)	L4	60.8±3.0	66570.0±5374.0^{bcd}
2:3 (Xanthan:LBG)	L4	50.3±8.6	61500.0±9899.5^{cde}
3:2 (Xanthan:LBG)	L4	51.3±4.5	61640.0±5543.7^{cde}
4:1 (Xanthan:LBG)	L4	39.8±8.2	47530.0±9418.7^{ef}
1:4 (LBG:Guar)	L2	44.3±3.9	289.5±57.3^{i}
2:3 (LBG:Guar)	L2	35.3±7.5	240.0±5.7^{i}
3:2 (LBG:Guar)	L2	29.5±1.2	177.0±7.1^{i}
4:1 (LBG:Guar)	L2	30.9±1.1	186.0±5.7^{i}
1:1:3(Xanthan:LBG:Guar)	L4	29.4±1.1	32295.0±2863.8^{fg}
1:2:2(Xanthan:LBG:Guar)	L4	72.4±3.4	86935.0±3995.2^{a}
1:3:1(Xanthan:LBG:Guar)	L4	48.4±0.2	53200.0±7014.5^{de}
2:1:2(Xanthan:LBG:Guar)	L4	60.5±4.6	72625.0±5508.4^{abc}
2:2:1(Xanthan:LBG:Guar)	L4	74.0±7.6	83645.0±1336.4^{ab}
3:1:1(Xanthan:LBG:Guar)	L4	73.3±4.5	88070.0±5501.3^{a}

*Mean ± Standard deviation (n=2). Means marked with different letters in the same column are significantly different (p<0.05).

CONCLUSION

As a conclusion, mixtures of xanthan/LBG solutions showed higher viscosity than xanthan/guar gum mixtures. The lowest viscosity obtained by each gum dissolution separately and LBG/guar gum mixtures. The strong interaction was found in xanthan, guar and LBG mixture when guar gum and LBG were present in roughly equal concentrations in solution. According to the results, the mixture of xanthan/LBG/guar gum as a ratio of 3:1:1 and 1:2:2 (w/v) was achieved 30-fold increasing in viscosity of xanthan gum solution. It has been evidenced that xanthan would dominant the structure arrangement and rheological properties of xanthan/galactomannan systems whereas LBG and guar gum ratio also play an important role in three mixed gum solutions.

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DEVELOPMENT OF FLAVORED MILK WITH CAROB

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ABSTRACT

Dairy products are considered to be an essential part of a healthy diet. Consumption of milk is of high importance especially for children who require calcium for development and maintenance of strong bones and teeth. However, children prefer other less healthy beverages due to their sweetness, aroma, taste and attractive appearance. Thus, ordinary milk products have to be made the way to be more appealing to children and still preserve their nutritional value. Flavored and sweetened milk beverages have quite high added-sugar content which is linked to cardiovascular diseases and obesity in children – big problem in developed world. This issue rises a need of developing new products, with lowered sugar content but still appealing to consumer. By taking this into account, carob can be good source because of its naturally high sugar content, which allows to get sweet milk beverage without using high amount of additional sugar, by contrast to chocolate milk. The aim of this study is development of new flavored milk beverage by using two different stabilizers, locust bean gum (LBG) and κ- carrageenan. A new flavored milk beverage with carob powder was developed by using different stabilizers. Two stabilizers, LBG and κ-carrageenan, were used at 0.1-0.3% and 0.01-0.03% concentrations, respectively. Based on the visual observations and measured values of viscosity, sedimentation and backscattering, the stability of carob milk during 8 days of shelf-life were discussed. Carob milk with no stabilizer showed severe sedimentation of carob powder particles. Carob milk samples prepared with κ-carrageenan had lower sedimentation than the ones prepared with LBG. Furthermore, LBG caused phase separation at concentrations of 0.1-0.3%. Aggregates of milk proteins and carob particles were observed in sample with 0.03% κ-carrageenan. Among the samples with κ-carrageenan, sample with κ-carrageenan at a level of 0.02% was observed to have the best appearance with no sedimentation. In conclusion, κ-carrageenan at a concentration of 0.02% can be used for preparation of carob flavored milk.

Key Words: *milk beverage, locust bean gum, κ-carrageenan*

RHEOLOGICAL PROPERTIES OF VEGAN PUDDING PREPARED WITH GUM ARABIC AND PECTIN

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ABSTRACT

The puddings are semisolid desserts which have a complex mixture and mainly composed of milk, starch, sugar, and thickeners. Since the veganity is a type of diet that is free from dairy products, in this study replacement of cow's milk with milk substitutes was performed. In order to discuss the rheological similarities and differences between puddings, and to characterize the rheological behavior of vegan puddings, nine pudding systems with a completely randomized factorial design were selected as an experimental conditions: 3 types of milks (coconut milk, almond milk and cow's milk (reference sample), 2 types thickeners (Arabic gum and pectin) and three thickeners concentration (0/100%, 50/50%, 100/0 %). The rheological behavior of samples was characterized by using a rheometer (Haake Rheostress 1, Germany) equipped with the cone-plate system (C35/2, a cone with d: 35 mm, angle: 2DEG; gap 0.105 mm) at 10°C and results were fitted to the Ostwald de Waele model. Consistency index (*K*), flow behavior index (*n*) and the apparent viscosity at shear rate 50 s^{-1} (η_{50}) varied between 11.12 to 43.97 ($Pa.s^n$), 0.407 to 0.540 and 1.703 to 5.963 (Pa.s), respectively which as $n<1$ indicated that all puddings showed shear thinning behaviour. Also, maximum values for *K* and η_{50} were belong to coconut pudding with 100% Arabic gum and maximum values for *n* was shown by almond milk with 100% pectin. The results showed that at 50/50% pectin/Arabic gum mixture, almond pudding and at 100% Arabic gum mixture, coconut pudding had an apparent viscosity similar to cow milk pudding viscosity. Meanwhile, puddings prepared with cow and coconut milk had a maximum and minimum viscosity at 100% Arabic gum mixture and 50/50% pectin/Arabic gum mixture, respectively. However, almond milk had a maximum and minimum viscosity at 50/50% pectin/Arabic gum mixture and 100% Arabic gum mixture, respectively. Results specify that the almond and coconut milk with different ratio of pectin and Arabic gum have the potential to produce vegan pudding at an industrial scope.

Key words: *rheology, viscosity, pudding, coconut milk, almond milk, vegan*

WASTE TO WORTH: VISCOELASTICITY AT THE INTERFACE

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ABSTRACT

In this present work, viscoelastic properties of the interface between revalorized sunflower protein isolate and sunflower oil aimed to be characterized. Protein isolate solutions are prepared at different pH values in order to identify varying solubility capacities of sunflower protein isolates. Fluid behavior, viscosity, storage and loss modulus are determined using rheometer with a double wall ring (DWR) geometry. Time and frequency sweep procedures are conducted to monitor structural behavior of the interface. pH values that are far away from isoelectric points of protein isolates at which proteins are most soluble are not the most capable ones to build most stable emulsion networks. Solubility is known as the primary specification required to set a stable emulsion but not sufficient alone for continuous interface network. To estimate emulsion stability of proteins isolates at different pH values, interfacial rheological behaviors are the most accurate functional tools to be ever used.

Key Words: *interfacial rheology, viscoelasticity, emulsion stability, sunflower protein*

EFFECT OF LECITHIN AND PEA PROTEIN ISOLATE ON DOUBLE EMULSIONS

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ABSTRACT

This study was performed to investigate the effect of lecithin and pea protein isolate (PPI) on double emulsions. For the preparation of primary emulsion, powder and liquid lecithin was used as emulsifier in oil phase which was prepared with sunflower oil. In the second step of emulsion preparation, Tween 80 or PPI were used. Particle size measurements and microscopic observations were performed. Moreover, emulsions were observed for 30 minutes. It was found that the use of 3 and 5% liquid lecithin in the external phase contributed double emulsion whereas 1% lecithin did not promote emulsions. Furthermore, unstable double emulsions were observed depending on varying concentration of lecithin and PPI. Microscopic observations also proved that emulsions were double emulsions.

Key Words: *double emulsion, emulsion stability, lecithin, pea protein isolate*

INFLUENCE OF DIFFERENT WALL MATERIALS ON EMULSION STABILITY AND DROPLET SIZE OF EMULSIONS PREPARED WITH HAZELNUT OIL

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ABSTRACT

The stability of food emulsions is very important during storage. Hazelnut oil has a growing importance in the dietary and cosmetics industry due to the presence of various micronutrients that need protection from deterioration. This study was performed to investigate the influence of different type of wall materials for the preparation of emulsions with hazelnut oil prior to microencapsulation. Maltodextrin (MD) was mixed with different bio-polymers including waxy maize starch (Em-Cap 12633TM), gum Arabic (GA), whey protein concentrate (WPC), gelatin (GE), pea protein (PP) and sodium caseinate (SC), at a ratio of 90:10. The prepared emulsions were characterized for stability, viscosity and droplet size. The best emulsion stability was obtained for MD:Em-Cap, MD:GA and MD:SC combination, while the lowest emulsion stability was obtained for MD:PP followed by MD:GE and MD:WPC. The obtained results demonstrated that droplet size distributions of the stable emulsions prepared with MD:Em-Cap, MD:SC and MD:GA were in the range of 2-5 μm. Moreover, the stability study revealed that the emulsions prepared from MD:Em-Cap starch, MD:SC and MD:GA were kinetically stable more than 5 days at room temperature.

Keywords: *encapsulation efficiency, emulsion stability, hazelnut oil, wall materials*

PREPARATION AND PROPERTIES OF NANO-ENCAPSULATED WHEAT GERM OIL AND ITS USE IN THE MANUFACTURE OF LABNEH

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ABSTRACT

This study aimed to enhance the nutritional and health properties of labneh without changing its characteristic properties by inclusion of wheat germ oil (WGO) in its composition. WGO was encapsulated in casein micelles (CM) of reconstituted skim milk in order to improve its oxidative stability before its use in labneh. Different levels of WGO (0.3-1.2%) were encapsulated in CM with high encapsulation efficiency (>95%) by pH cycling assisted with ultrasound treatment. The encapsulated WGO had a spherical shape and its size increased with the increase of the level of encapsulated WGO. The encapsulated WGO retained high DPPH scavenging activity and exhibited high oxidative stability after UV exposure up to 18 h. Labneh was made by replacement of 50% of milk fat with encapsulated and non-encapsulated WGO and the product had composition and quality comparable to the control while labneh made with non-encapsulated WGO exhibited significantly different properties from the control.

Key words: *labneh, casein micelles, encapsulation, oxidative stability, wheat germ oil*

EFFECS OF FEED SOLUTION VISCOSITY ON ELECTROSPINABILITY OF ZEIN WITH OR WITHOUT SAFFRON

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ABSTRACT

Saffron is well-known for its flavouring, antioxidant and antimicrobial properties. This study illustrates the effects of various zein-saffron concentrations on nanofiber morphology and fiber diameter. Fiber-forming zein solutions (15%, 25% and 30% w/v) were prepared by dissolving zein powder in aqueous ethanol solution (80% v/v). The zein polymer solutions were then mixed with saffron extract (5%, 10% w/v). The optimal conditions for forming bead-less fibers were determined. The applied voltage was set up to 18 kV, tip-to-collector distance was kept at 15 cm. Viscosity of the polymer solutions were measured before electrospinning. Scanning electron microscopy was used to examine morphology and diameter of zein fibers in various zein and saffron concentrations. Effects of polymer solution properties and saffron concentrations on morphology and the potential practical applications of these fibers were also studied. The results demonstrated that saffron loaded zein nanofibers could be a good candidate for food based applications and has the potential for further applications in delivery systems. In addition, zein nanofiber encapsulated saffron may also be studied as a food packaging material for antimicrobial food packaging.

Key Words: *saffran extract, zein nanofibers, electrospinning, encapsulation*

EFFECT OF VISCOSITY ON ELECTROSPINNABILITY OF FEED SOLUTIONS CONTAINING PLGA (Poly Lactic-co-Glycolic Acid)

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ABSTRACT

Electrospinning is the one of the effective nanoencapsulation methods. The release of nanofiber encapsulated active ingredients can be tailored as needed. The wall material has a great deal of importance during controlled release of any given active ingredient. Poly (lactic-co-glycolic acid) (PLGA), which is approved by the FDA, is one of the most common polymer used in electrospinning processes because of its biodegradability and its potential for enabling the prolonged and controlled release of active agents. Moreover, PLGA is preferred for its ability to pass through blood-brain barrier for heailing of some brain diseases such as alzheimer, parkinson, epilepsy. It can be broken down in the body. In this study, the effect of viscosity of the feed solutions containing PLGA was studied. PLGA is dissolved at 0.5, 4, 8, 12% in the mixture of aceton: dimethylformamide (90:10) at 100 rpm for 2 hr. Then, they were fed to the electrospinning equipment. The feed rate, applied voltage and distance to the collector plate were 1 ml/hr, 16 kV and 7 cm, respectively. The 21G needle was used for the electrospinning. The viscosity measurements of the feed solutions were conducted by using a rheometer (Haake Rheostress1, Germany) equipped with a parallel-plate system (dia 35 mm, gap 1 mm) at room temperature in duplicate. The resultes were modelled by using power-law model. The consistency index and flow behavior index values were between 0.05-0.14 ($Pa.s^n$) and 0.92-0.94, respectively. According to the results, PLGA was found as electrospinnable for all viscosity values studied, even in low concentrations (0.5%).

Key Words: *PLGA, blood brain barrier, electrospinning*

IMPORTANCE OF RHEOLOGY IN EMULSION ELECTROSPINNING

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ABSTRACT

High surface to volume ratio and ultrafine structure are the main advantages of electrospinning compared to other techniques, however conventional electrospinning has its own drawbacks inside. At this point, emulsion electrospinnig offers a novel approach to produce nanostructures efficiently. Emulsion electrospinning is comprised of blend and coaxial electrospinning to overcome the disadvantages of these techniques. Feed solution which is an emulsion containing two or more immiscible phases stabilized with a proper surfactant differentiates emulsion electrospinning from blend electrospinning. Emulsion electrospinning enables ecofriendly production by limitation of solvent usage, makes incorporation of different materials possible and improves functional properties in nanostructure formation. Success of the electrospinning and morphology of the nanostructure depend on rheological properties of feed solution, which is composed of water and organic phases and surfactant in emulsion electrospinning as a result, properties of each of them affect electrospinnability and structure of the final product. Viscosity is a measure for chain entanglements in the solution and minimum viscosity and shear thinning behavior is necessary for stabilize the jet. While too low viscosity value causes non-uniform and beaded nanofiber formation, it is not possible to obtain any product with too high viscosity. Polymer and surfactant type and concentration, water phase fraction and molecular weight of solvents affect viscosity. Moreover, viscoelastic property of the polymer solution is another important point for uniform jet during electrospinning. Feed solution should possess high enough elasticity and extensional viscosity. To obtain uniform nanofiber storage modulus (G') and loss modulus (G'') should be at appropriate level and decrease at higher strain because when the caging of droplet will be very significant that could not be broken even at higher strain; otherwise, formation of beads and discontinuing in jet occur. Electrospinning process is applied under an electrical field and it is known that electrical field promote separation of emulsion by rupture of interfacial film and coalescence of droplets or may cause droplets breakup. It is expected that change in droplet size can affect viscosity and rheological properties; therefore, effects of electrical field on emulsion should be investigated.

Key Words: *emulsion electrospinning, rheological properties*

SOME RHEOLOGICAL PROPERTIES OF DIFFERENT HYDROCOLLOID SOLUTIONS AND THEIR EFFECT ON ENCAPSULATION EFFICIENCY

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ABSTRACT

Hydrocolloids are water-soluble macromolecules of high molecular weight, which can bind high amounts of water, and modify the rheology of aqueous systems to which they are added. They are used in food industry for different purposes such as thickening, gelling, stabilizing, and emulsifying agents. The aim of this study was to determine flow behavior and viscosity of different hydrocolloid solutions and their effect on encapsulation efficiency. In this study, 1% of nine different hydrocolloid (gum arabic, pectin, carboxymethyl cellulose, methyl cellulose, carrageenan, locust bean gum, gellan gum, xanthan gum, and guar gum) solutions were prepared. Rheological analyzes were performed by using Anton Paar/MCR-302 device. CP25-2 cone plate was used as measuring system. The distance between the two plates was 0.106 mm. The shear rate was linearly increased from 1 to 100 s^{-1}. Rheological analyzes were carried out at 25°C. On the other hand, different phenolic compounds were microencapsulated by using ionic gelation technique. Sodium alginate (2% w/v) and hydrocolloids (1% w/v) were used as wall material and for cross-linking 2% (w/v) calcium chloride solution at 4°C was used. Encapsulation efficiency analyzes were performed by using HPLC. All analyzes were performed at least two replicates and three parallels. All hydrocolloid solutions have showed pseudoplastic flow behavior. As the shear rate increases, the viscosity values of the hydrocolloid solutions decrease. Considering apparent viscosities of hydrocolloid solutions at 50 s^{-1}, gum arabic has the lowest viscosity value with 1.0 mPa.s while guar gum has highest viscosity value with 549.6 mPa. The results of encapsulation efficiency analyzes show that using more viscous hydrocolloid as wall material enhances the efficiency. According to our study, viscosity of hydrocolloid as a wall material is also important parameter for obtaining higher encapsulation efficiency. While selection of hydrocolloids, viscosities should be considered.

Key Words: *rheology, hydrocolloid, encapsulation efficiency, ionic gelation*

THE IMPORTANCE OF RHEOLOGICAL PROPERTIES IN ENCAPSULATION APPLICATIONS

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ABSTRACT

Rheology is a branch of science that examines the deformation of solids and the flow of liquids. In food technology, rheological properties are importance for the determination of the properties of raw materials and of the products obtained, as well as the production process. Some food components are affected by some factors e.g. temperature, light, pH, oxygen and moisture. For this purpose, encapsulation processes are applied to ensure the stability of food products. By encapsulating the active ingredients with the coating materials (maltodextrin, gum arabic, gelatin, starch, pullulan, alginates, carrageenan, lactose, sodium caseinate, whey concentrate, etc.), these components are protected from adverse environmental conditions, the shelf life of the product is increased, and the encapsulated material is released in a controlled. With the application of rheological tests in encapsulation processes; the correct selection of the encapsulation method, determination of the quality levels and utilization rates of the raw materials, as well as the degradation of carbohydrates and proteins can be determined. Determination of the rheological and textural properties of products is important in encapsulation applications for the purposes such as determining of physical stability and quality by determining the structural changes occurring depending on time and temperature of the food in the shelf, and determining the applicability of the product.

Keywords: *rheology, texture, food, encapsulation, stability*

DETERMINATION OF OPTIMUM ROASTING CONDITIONS OF *PISTACIA TEREBINTHUS* BEANS IN A FLUIDIZED BED ROASTER USING RESPONSE SURFACE METHODOLOGY

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ABSTRACT

Roasting conditions of *Pistacia terebinthus* beans to be a promising caffeine-free alternative to coffee due to their similar aroma and flavor to conventional roasted coffee beans were investigated. *P. terebinthus* beans were roasted at 180, 200 and 220°C for 5, 20 and 35 min at each roasting temperature. A three-level two factor (3^2) full factorial design was used to determine the effects of the roasting conditions on color, moisture content, density, breaking force and sensory properties of the *P. terebinthus* beans. Antioxidant activity and total phenolic content of roasted beans were also evaluated. *L** value, moisture content, density and breaking force of roasted *P. terebinthus* beans decreased with increasing roasting temperature and roasting time. Dark roasted *P. terebinthus* beans took the highest acceptability scores in acceptability tests by the panelists. The changes in physicochemical properties and sensory attributes during roasting were successfully described by the quadratic models developed and using response surface methodology (RSM). Quality attributes of the roasted *P. terebinthus* beans were significantly ($p \leq 0.05$) affected by the roasting temperature and roasting time. Based on the superimposed contour plot, optimum region of roasting temperature and time was determined.

Key Words: *Terebinth bean, degree of roast, physicochemical property, sensory attribute*

INTRODUCTION

Coffee consumption has been increasing throughout the World [1]. With the increase of coffee consumption, people seek a caffeine-free coffee due to the negative effects of caffeine [2]. To reduce negative effects of caffeine, ideal approach is to increase the consumption of decaffeinated coffee, but consumers have some negative perception about the decaffeinated coffee so they are not usually willing to consume it. Alternatively, some herbal coffees are present in the market to reduce negative side effects of excessive coffee consumption, but their consumption is very limited because their taste is different from the typical coffee taste. Since *P. terebinthus* fruit after roasting has a similar aroma and flavor to conventional roasted coffee beans, and it has a high antioxidant capacity [3], it can be a promising caffeine-free alternative to coffee.

Roasting process gives desired aroma and flavor to *P. terebinthus* beans. Pan roasting and conventional roasting traditionally used for roasting of *P. terebinthus* beans. Conventional roasting is carried out at high temperatures with long times. Pan roasting is based on conduction heating and causes uneven

roasting. On the other hand, fluidized bed roasters operate high temperature short time principle, and fluidized bed roasting provides intense bean movement allowing uniform roasting of beans [4]. Commonly used criteria for evaluating the quality of roasted coffee beans include measurements of color, moisture content, density, texture and organoleptic properties [5]. Although roasted *P. terebinthus* could be a caffeine-free alternative, there is no study reported for the optimization conditions of *P. terebinthus* beans by fluidized bed roasting by taking into account antioxidant activity and total phenolic content of roasted beans.

MATERIALS and METHODS

Materials

P. terebinthus beans were purchased from a local market in Istanbul, Turkey.

Methods

A three-level two factor (3^2) full factorial design was used as the experimental design. The independent variables (factors or inputs) were roasting temperatures (x_1) and roasting time (x_2). The levels of factors were chosen based on the commercial roasting conditions of coffee in which three different roasting temperatures (180, 200 and 220°C) and three different roasting times (5, 20 and 35 minutes) were used. The dependent variables (responses or outputs) were color parameters (*L**, *a** and *b**), moisture content, density, breaking force and sensory properties (appearance, odor, texture, flavor and overall impression) of the roasted beans**.** The responses were assumed to be related to the independent variables by a second degree polynomial using the equation below:

$$y_n = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_{11} x_1^2 + \beta_{22} x_2^2 + \beta_{12} x_1 x_2$$

where, β_0, β_1, β_2, β_{12}, β_{11} and β_{22} are constant coefficients, and x_1 and x_2 are coded independent variables. Experimental design is presented in Table 1.

Table1: Experimental design including process variables and their levels

Coded variables			Uncoded variables	
Treatments	x_1	x_2	Temperature, T (°C)	Time, t (min)
1	-1	-1	180	5
2	-1	0	180	20
3	-1	+1	180	35
4	0	-1	200	5
5	0	0	200	20
6	0	+1	200	35
7	+1	-1	220	5
8	+1	0	220	20
9	+1	+1	220	35

*Experimental runs were performed in random order

Measurements

Color Measurements

Color measurements of samples were performed using a Konica Minolta CR-400 (Konica Minolta, Sensing Inc., Osaka, Japan) chroma meter equipped with a D_{65} illuminant source and operating with CIE L*a*b* color space. Calibration was performed with the white color calibration tile prior to the color

measurements. Agtron numbers are precise industry standard generally used to determine the level of roasted coffee. Therefore, the color values were transformed to Agtron values, and the roasting level of *P. terebinthus* beans were determined based on the Agtron scale.

Moisture Content

Moisture content was gravimetrically determined based on the weight loss according to the procedure described in AOAC method 930.15 [6]. Results of the compositional analysis were the mean of three replicates.

Density Measurements

Density (ρ) of the beans was measured according to Lerici et al. [7] by using a pycnometer working based on volume displacement method using glycerine ($\rho_{20°C}$: 1.26 $kg.dm^{-3}$) at 20°C. Density measurements were done in triplicates, and the results were expressed as the mean value.

Determining of Breaking Force

A texture analyzer (Lloyd TA1, Lloyd Instruments Ltd., West Sussex, UK) was used to determine breaking force. Each bean was compressed by a cylindrical probe with a diameter of 6.30 mm at a constant deformation speed of 1 $mm.s^{-1}$ until failure occurred. A five kg load cell was used. Pre-test and post-test speeds were set to 1 $mm.s^{-1}$. Ten replicates for each treatment were tested, and the mean value was given.

Antioxidant Activity and Total Phenolic Content

Antioxidative activity was evaluated by DPPH radical assay, as previously described by Singleton et al. [8]. TPC was determined by Folin and Ciocalteu method, and the results were expressed as gallic acid equivalent [9].

Sensory Acceptability

Sensory evaluation was carried out with 9 panelists (5 females and 4 males) by considering the guidelines in the norm ISO 8586 [10]. The intensities of appearance, texture, odor, flavor and overall impression were evaluated using a five-point hedonic scale (1=dislike very much, 2=dislike, 3= neither like/nor dislike, 4=like and 5=like very much) [11]. Panelists were chosen from the staff members of Chemical Engineering Department in Gebze Technical University who have an experience in sensory evaluation. When the panelists were repeatable and consistent, individually and collectively, in their evaluations, they were considered ready to serve in a panel. Repeatability and reproducibility in evaluations were checked and verified in accordance with the method proposed by Rossi [12]. Acceptance tests for the samples of roasted *P. terebinthus* beans were carried out by the panelists in isolated sensory booths illuminated with white fluorescent light in an environmentally controlled room (23 ± 2°C and 50 ± 5% RH) under standardized conditions based on the norm ISO 8589 [13]. Samples were placed into odor-free, disposable and white ceramic plates labeled with randomly coded three digit numbers and presented to the panelists in a randomized order. Each sample was presented to each panelist along with the appropriate questionnaire, one at a time, with a 3 min wait between the samples.

Statistical Analysis

Analysis of variance (ANOVA), a partial *F*-test for individual terms, and an analysis of residuals were performed to determine the significance of each factor. Model diagnostics were done by generating normal probability plot, and the plots of residual versus predicted values, and observed versus predicted values. The degrees of significance of all terms in the polynomial were determined statistically by calculating the *F*-value at a probability (*p*) of 0.001, 0.01, or 0.05. Contour plots showed changing the responses with respect to the factors and obtained graphical representation of the response surface. All statistical analyses were performed using MINITAB® (Release 16.1, Minitab Inc, State College, PA, USA).

RESULTS and DISCUSSION

Effect of Roasting on Color

*L** and *b** values decreased while *a** value increased with increasing roasting temperature and roasting time during roasting. Models developed for three responses (*L**, *a** and *b**) were significant ($p \leq 0.001$) with no significant lack of fit suggesting that they adequately represented the relationship between the responses and factors.

Effect of Roasting on Moisture Content, Density and Texture

During roasting, moisture content of *P. terebinthus* beans decreased with increasing the temperature and time. A decrease in density occurred with an increase in the roasting temperature and time. The roasting process affected textural property of the beans as evidenced by the decrease in the breaking force with the increase in the roasting temperature and time. Models developed for the moisture content, density and breaking force were significant ($p \leq 0.001$) with no significant lack of fit suggesting that the models adequately represented the relationship between the responses and factors.

Effect of Roasting on Sensory Acceptability

The appearance, odor, texture, flavor and overall impression scores increased and then decreased with increasing roasting temperature and time. Very light roasted and very dark roasted samples took low sensory scores by the panelists. Samples roasted at 200°C for 20 minutes had the highest appearance, odor, texture, flavor and overall impression values. The models developed for five responses were significant ($p \leq 0.001$) with no significant lack of fit suggesting that the models adequately represented the relationship between the responses and factors. The regression equations obtained were used to generate contour plots (Figure 1).

Effect of Roasting on Antioxidant Activity and Total Phenolic Content

Roasting caused an increase in antioxidant activity and total phenolic content. This was attributed to the formation of novel antioxidant substances and new phenolic compounds during roasting. Further roasting caused partial degradation of some compounds contributing to antioxidant activity and total phenolic content.

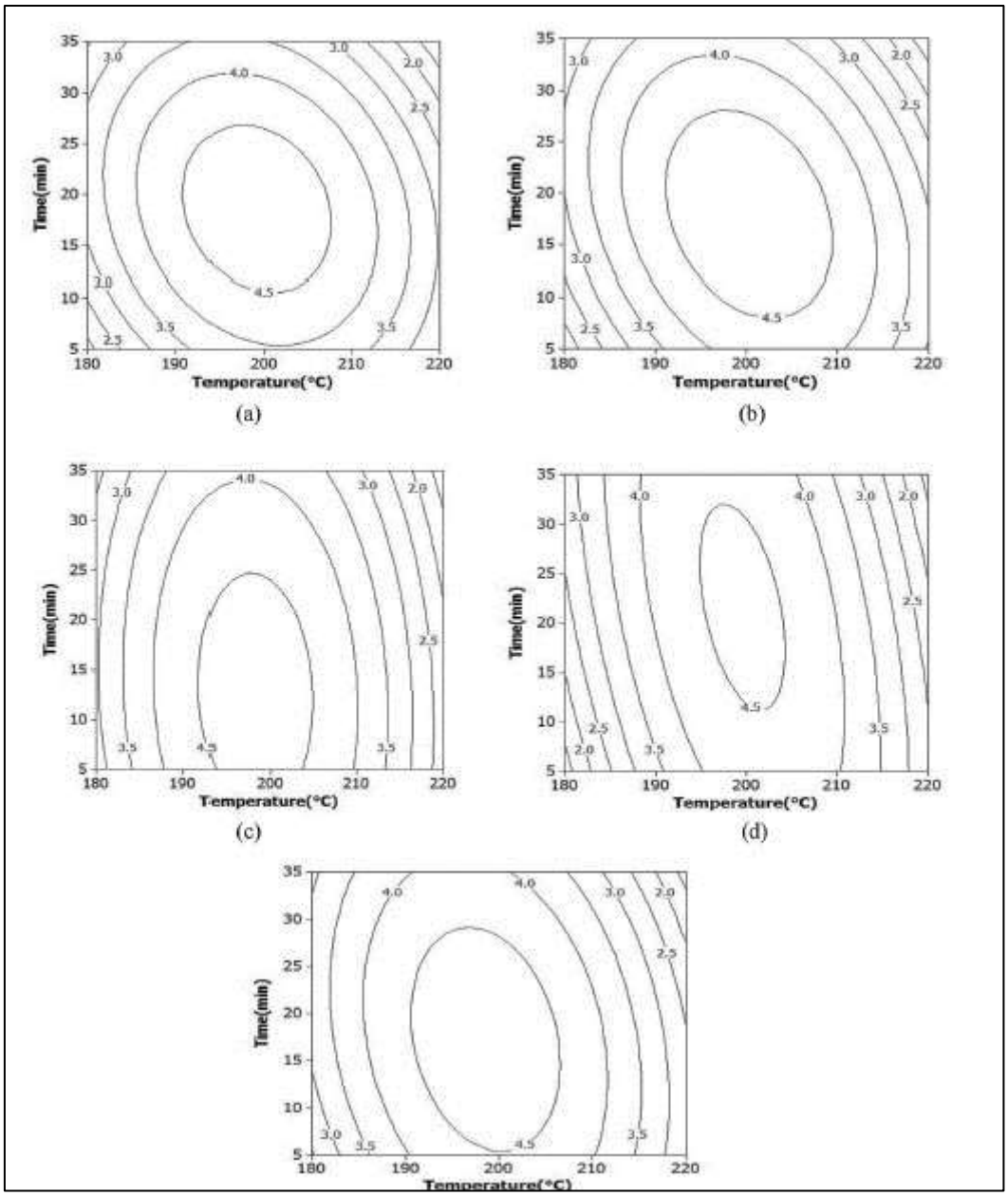

Figure 1. Contour plots for (a) appearance, (b) odor, (c) texture, (d) flavor and (e) overall impression of roasted *P. terebinthus* beans.

Determining Optimum Roasting Conditions

Optimal roasting conditions of temperature and time were obtained by superimposing the contour plots for the responses. Many dark roasts are used for espresso blends because more balanced flavors and aromas develop as the roasting process proceeds, and the taste of the coffee becomes more intense. Therefore, the *L** value, moisture content, density and breaking force corresponding to the dark roasting level based on the Agtron description were used as constraints to determine the optimum region. Overall impression score of at least 4 (like) was chosen as the minimum value for the acceptability (Figure 2).

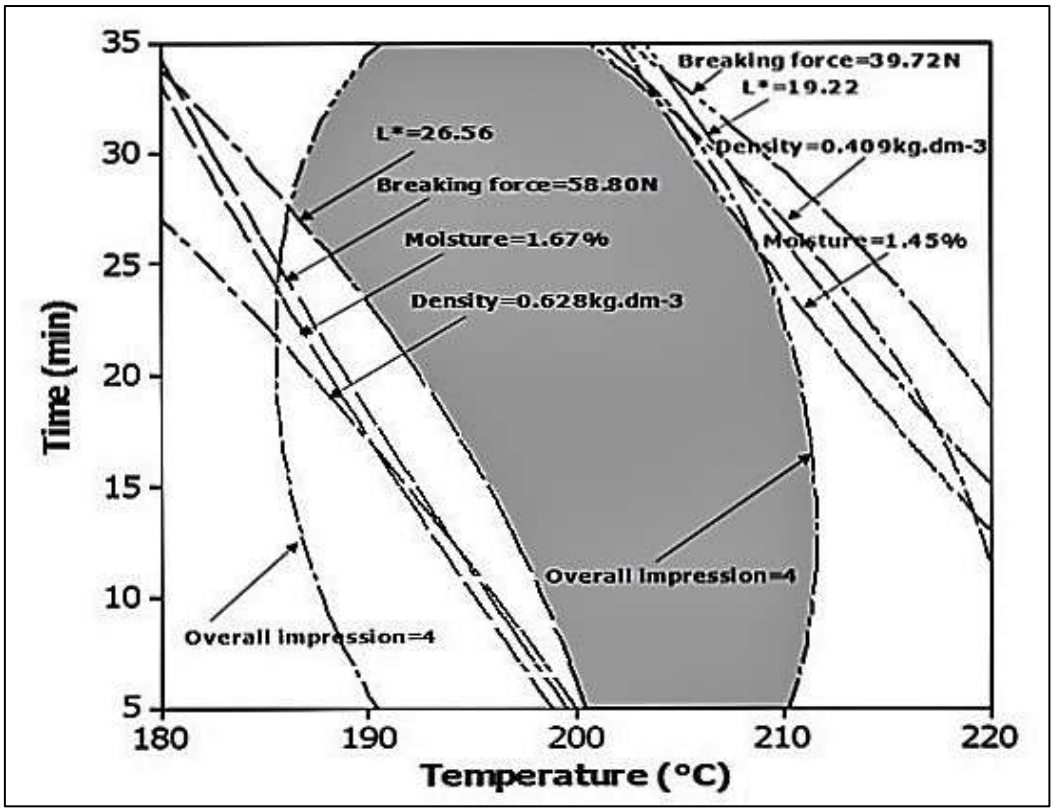

Figure 2. Optimum region obtained by superimposing contour plots of overall impression, *L** value, moisture content, density and breaking force.

CONCLUSION

The results of this study showed that roasting temperature and roasting time are the important factors affecting the physical, chemical, structural and organoleptic properties of the roasted *P. terebinthus* beans. RSM was effective in producing the predictive models, establishing the relationships between the processing factors and the responses, and defining the optimum region for the roasting conditions. Predictive models, derived from second-degree polynomial, adequately described the roasting characteristics and sensory *P. terebinthus* acceptability as a function of roasting temperature and time. Roasting conditions yielding *P. terebinthus* beans with optimum acceptability were determined. Therefore, by using RSM, it was possible to define the optimum roasting conditions for *P. terebinthus* beans. This information obtained herein can be used by the roasters to determine optimum roasting conditions for products containing with desired quality properties. Fluidized bed roaster is highly recommended for roasting of *P. terebinthus* beans to obtain beans with desirable aroma and flavor.

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EFFECTS OF RAW MATERIALS ON RHEOLOGICAL PROPERTIES AND BAKING STABILITY OF THE OIL BASED CREAM

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ABSTRACT

Filling cream is used in the many products such as cake, wafer, biscuit to improve attractiveness. The cream is generally composed of cocoa powder, vegetable oil (free fatty acid max 0.2% as oleic acid) milk powder, crystal sugar, hazelnut puree and emulsifiers. Ball mill technology is used for the grinding process. Baking stability of consistency of the filling cream is an important characteristic for the product to achieve consumer acceptability. Therefore, in the present study the effects of raw materials present in the formulation on the rheological properties, baking stability, melting profile, particle size distribution and textural characteristics of the cottonseed oil-based cream were investigated. For this aim, independent factors were selected as amount and type of cocoa powder and fat, whole milk powder, emulsifier and solid fat concentration. In addition, the effects of grinding rate and time were also studied in the study. Baking stability was observed by comparing rheological properties (yield stress value and Casson viscosity) of the cream before and after heat treatment application at 25°C and by measuring viscosity of the sample with respect to temperature ranged between 20 and 80°C.

As a result of the study, it was investigated that cocoa powder increased the yield value, Casson viscosity and the amount of combustion resulting from heat treatment. Type and amount of solid fat used in the product formulation was observed as the most effective raw material considering rheological properties and thermal stability. Oil binding capacity of milk proteins increased the thermal stability of the cream by preventing propensity for boiling at high temperature. After heat treatment, the cream sample with higher Casson viscosity (values are between the range of (0.7 – 1.9 Pa.s) kept its fluid structure more.

Key Words: *filling cream, baking stability, rheology, formulation*

RHEOLOGICAL CHARACTERIZATION OF PROTEASE TREATED LIQUID EGG WHITE

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ABSTRACT

Eggs are a high-quality protein and full of nutrients. Egg and its products have functional properties such as foaming, emulsifying, and structure which make them useful ingredients in food products. Liquid egg white (LEW) is a multifunctional ingredient used in foods. Egg white is a widely used and key ingredient for many food products such as bakery products, sausages, high protein foods, meringues and meat products. LEW are also highly perishable. Pasteurization (55.6°C and 6.2 min.) of LEW is commercially performed in high-temperature-short-time equipment. This heat treatment affects the functional, rheological and physio-chemical properties of LEW. Yolk contamination is also a critical issue since it affects stability of white form and voluminous foams. In this study, rheological behaviours of LEW treated with protease enzyme with different concentrations (0.5, 1 and 1.5%) at 45°C with 2 hours duration were evaluated. Results show that using protease enzyme with different concentrations (0.5; 1 and 1.5%) significantly ($p<0.05$) increased the resistance of applied frequency compared to untreated samples.

Key Words: *liquid egg white, rheology, flow behaviour, enzyme treatment, protease*

INTRODUCTION

Eggs *(Gallus domesticus*) have high nutritional value for human diet, which is excellent source of highly digestible protein, vitamin, mineral, essential amino acids and fatty acids [1, 2]. Eggs provide a unique, well-balanced source of nutrients for people of all ages and are an ultimate source of protein which one egg provides 6-8 grams of protein with only 70 calories [3]. Egg products, that is eggs removed from their shells and processed to liquid, frozen and dehydrated egg products have functional properties such as foaming, emulsifying, and gelling which make them useful ingredients in foods such as noodles, mayonnaises, desserts, cakes, formulated meat and confectionery products [3-6]. Among food products prepared with eggs; mayonnaise, sauces, cakes, decorations, sports products, pasta, ice cream, baby biscuits, soups, sports drinks, nougat, halva, Turkish ravioli, noodles, macaron, waffles, chocolate and cream varieties are existing. Egg is used extensively in the food production for the purpose of gelation, foaming, crystallization retardants, binders, colorants, flavour-giving, volume receive, blistering or emulsifier thanks to its functional features [2, 8-10].

Liquid egg white is a multifunctional ingredient used in food. Liquid egg white (albumen) is a desirable key ingredient for many food products such as bakery products, sausages, high protein foods,

meringues and meat products. Liquid egg albumen is a common form of industrial egg white, like whole egg and egg yolk, should be free from pathogenic bacteria and particularly Salmonella, and because of that need to be pasteurized under certain conditions. But heat treatments can have detrimental effects on the functional/flow properties of egg proteins resulting in commercially undesirable finished products [7]. Egg white is more sensitive to higher temperature than whole egg or egg yolk due to the possibility of coagulation of protein. Because of this limitation in the industry, there is increasing interest to alternative methods, especially in the processing of egg albumin. For the improvement, the quality and extend the shelf life of liquid egg white, effective new methods are needed. Nowadays, along with the new methods, enzymes are used as processing aids holding an important place. Enzyme modified egg is one of the fastest growing products in the egg processing industry. Also, processing parameters to produce enzyme modified egg products are important.

Protease enzyme is a part of important processing aid ingredients for egg processing solutions of albumen. The influence can be eliminated by using protease enzyme *Mucor miehei* lipase and can be prevented by using optical sensor separation technology, air pressure, or vibrating the egg yolk cases [8].

Rheological flow behaviours of fluid food are necessary for designing and evaluation of food processing lines, quality control and engineering calculations. In this study, flow behaviour and the effect of enzyme concentration level on rheological properties of liquid egg albumen were determined. Nowadays for the purpose of the preservation of quality and increase the shelf life of eggs and egg products pasteurization technique is utilized. However, heat treatment can damage the functional properties, flavour and structure of liquid egg [9-11]. Because of this limitation in the industry, there is increasing interest to alternative methods in processing of egg albumin. Belong with the new approaches; enzymes used as processing aids holds an important place. It has been observed a limited number of publications upon the processing eggs the use of new method, especially upon improving the quality of liquid egg and the extension of shelf life [12, 13]. The use of the enzymes such as phospholipase, lipase and protease becomes widespread in the egg products industry. Enzyme modified egg products give chance to produce special product with high added value which cannot be produce with conventional techniques. Optimizations can be made in the process in terms of maintaining the functional quality of egg products during the production process can take some precautions, but there is no method that can be applied to improve its functional/flow properties, it can only provide the expected functional/structural recovery from enzymes as processing aids in this regard. Today, the use of enzymes in the food industry is growing rapidly and functional and structural recovery is recorded in enzyme modified liquid egg products. The rheological characterisation of enzyme treated eggs will be in use of equipment designs such as pumps, agitators, heat exchangers and homogenizers or engineering calculations which are necessary for the design of processes associated with this equipment, component specifications in the product development process and determining the functional effect, quality control in process phase, shelf-life tests are needed regarding the structural evaluation of the egg.

In this study, determination of the rheological properties of liquid egg whites treated with different concentrations of protease enzyme. The effects of enzyme concentration on rheological behaviours of

liquid egg albumen was studied and the rheological characteristics of enzyme modified liquid albumen was better understood.

MATERIALS and METHODS

Liquid Egg Albumen

The commercial pasteurized liquid egg white (*Gallus domesticus*) samples were provided directly from the processing line of Keskinoglu egg processing plant (Akhisar, Manisa, Turkey) without any additives. Liquid egg samples transported between 0-4°C in cold chain to laboratory.

Enzyme Preparation and Treatment

In this study, a commercial protease produced from microbial fermentation techniques was supplied from Biocatalysts Ltd. (Promod 194SP, Wales, UK). All the liquid egg albumen samples were prepared under the conditions proposed by the manufacturer (time, pH and temperature) and incubated with the protease enzyme at different concentrations (1.5, 1.0 and 0.5% v/v) at 45°C with 3 hours in a with the aid of magnetic stirrer and special unit (heating and water circulation) made for minimizing the protein denaturation. The concentrations of all enzymes used during experimentation were determined through trial and error.

The study was guided by the following test pattern.
a) Control (untreated liquid egg albumin)
b) Protease enzyme 1.5% treated liquid egg albumin,
c) Protease enzyme 1.0% treated liquid egg albumin,
d) Protease enzyme 0.5% treated liquid egg albumin.

Rheological Measurements

Rheological measurements were carried out with a controlled stress rheometer (DHR-2, TA Instruments, New Castle, DE, USA)-using software (Rheology Advantage Data Analysis Program, TA). Parallel plate geometry (40 mm diameter, 1 mm gap) was used for the experiments, plate was equipped with a Peltier temperature control that allows rapid temperature control [14]. A sample volume of approximate 1.35 mL of liquid egg albumen was placed between the parallel-plates using an automatic pipette. All experiments were performed triplicate. Rheological measurements were done after the enzyme treatment of each treated liquid egg albumen sample.

Flow ramp test was performed in the presence and absence of protease enzyme, from low shear rate (0.01 s^{-1}) to high shear rate (100 s^{-1}) during 150 s at 25±0.01°C. Rheological parameters (shear stress (σ), versus shear rate (γ), apparent viscosity) were obtained from the software. Various rheological flow models based on shear stress–shear rate was tested (Newtonian, Bingham, Casson, power law, Herschel Bulkley) and the best-fit model was selected based on R^2 value. Experimental flow ramp curves were fitted to the Herschel-Bulkley model [15]. To find the most suitable % strain in the linear viscoelastic region (LVR) of liquid egg albumen, oscillation amplitude test was performed. Test parameters were determent as follows; angular frequency 20 rad/s, temperature 25°C and the % strain varying the value

from 0.01% to 100%. This test result used in the subsequent analysis and the process is reconstructed for each sample [16]. Oscillation frequency test was carried out between the range of frequency 0.01 and 10 Hz at 25°C and using the appropriate % strain value from a previous analysis result [14, 17]. Oscillation temperature ramp was performed from 40°C to 70°C with the heating rate 1°C/minute. % Strain value obtained from previous oscillation amplitude test was used and angular frequency was set to 20 rad/s. The coagulation temperatures were determined by extrapolating the rapidly rising storage modulus (G') to intercept the temperature axis [18]. Herschel-Bulkley model parameters were calculated using the following equation:

$$\sigma = \sigma_0 + K\gamma^n$$

where σ_0 is the yield stress (Pa), K is the consistency coefficient (Pa.s^n), and n is the Herschel–Bulkley flow behaviour index.

RESULTS and DISCUSSION

Rheological properties of protease enzyme treated and non-treated liquid egg white were determined. The rheological property of treated albumen was studied and the results were shown in Figure 1. The liquid egg white samples behaved as a pseudoplastic fluid. The R^2 was 0.98 and fitted best with Herschel-Bulkley model and flow behaviour index ranged between 0.78 to 2.29. The viscosity values were 0.02 Pa.s for control sample and reduced with enzyme treatment. According to the flow ramp results obtained in rheological measurements performed in the study, viscosity, which is the ratio of shear stress and shear rate of liquid egg white sample was measured. It was determined that viscosity values of enzyme treated liquid egg whites were lower than those of the control group (Figure 1). Liquid egg whites seemed to have a decreasing viscosity at increasing shear rates and it could be said all samples showed shear thinning behaviour. A rapid decrease in viscosity was observed in all samples with increasing shear rate. This indicating that all samples behave as non-Newtonian (pseudoplastic), shear-thinning fluids [19]. Rheological behaviours of liquid egg described by shear stress, shear rate curve (flow curve). According to flow ramp curves of control and protease enzyme modified liquid egg white sample, by adding enzymes to the liquid egg white, regardless of the amount of concentration, viscosity of the system in all treated samples decreased and structure showed shear thinning behaviour. It is noted that decrease the viscosity for thick and thin albumen in literature [20].

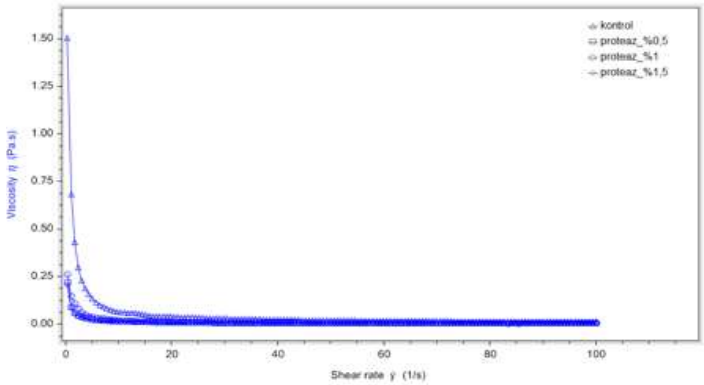

Figure 1. The change of the viscosity of examples protease enzyme modified liquid egg whites with the shear rate (viscosity curve)

Oscillation amplitude curves of control and protease enzyme modified liquid egg white samples were presented in Figure 2. Viscoelastic characteristics of liquid egg white samples modified with protease enzyme were determined by applying frequency-scanning test in viscoelastic region and the elastic modulus and viscous modulus values changes with frequency were obtained (Figure 2). Accordingly, both the elastic modulus (G') and viscous modulus (G'') have been determined that increased depending on the frequency. G'' is reduced due to increase in frequency in the enzyme concentration of 1%. In all enzyme concentrations used in the study it is determined that with increasing frequency G'' is higher than G', and therefore obtained solution of the enzyme modified egg exhibits liquid-like nature. In enzyme concentration of 0.5% in the low frequency value (G''> G'') shows viscoelastic property, at the increasing frequency value (G'< G'') the protein system exhibits liquid behaviour. In fact, at high frequency with the G' and G'' curves it happened that G'> G'' and system will act as a viscoelastic solid. According to the obtained data there is no differencess between control group and enzyme added egg whites in property of gelling and emulsion structure; it can be expressed with the structure of the egg albumen, which has a very good gelling ability.

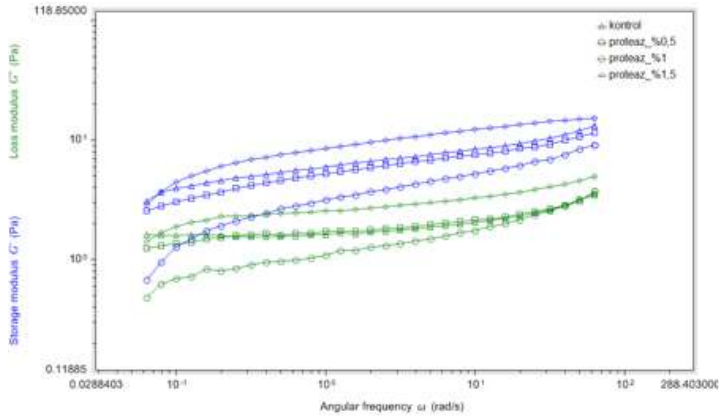

Figure 2. Protease enzyme modified liquid egg whites viscoelastic behaviour (elastic modulus- G', viscous modulus- G'') with frequency.

Frequency sweep curves of the control and protease enzyme modified liquid egg white sample are given in Figure 3 where the most appropriate stress value in linear viscoelastic was applied. G' is a measure of structural integrity, so that when there is a drop in this value, it shows a structural distortion and nonlinear initial. In this regard, high elastic modulus indicate the hardness of the sample, an extensive linear elastic region indicate that the sample maintains its structural integrity against the increased shear stress. In the graph; associated with increased protease enzyme concentration, loss modulus value decreased and depending on the increased frequencies loss modulus tends to increase. Frequency sweep results showed that the control group had higher G' and G'' values compared to those of protease enzyme modified liquid egg white samples. It indicates that the control group has a stronger structure, showing higher resistance to applied frequency.

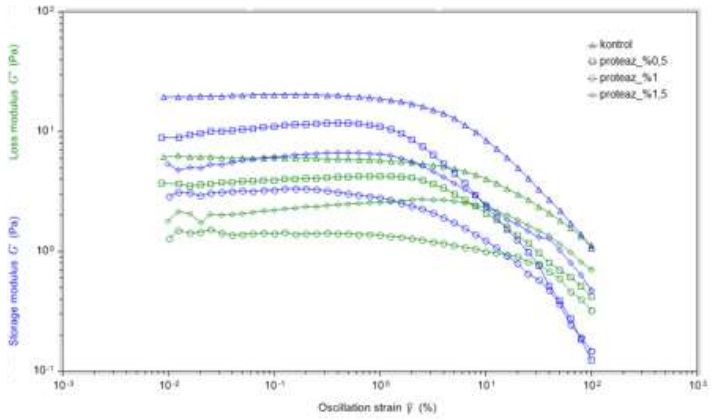

Figure 3. Deformation scan curve of examples protease enzyme modified liquid egg whites

Temperature ramp curves for control and protease enzymes modified liquid egg white samples was given in Figure 4. In the graph; depending on the increased protease concentration, loss modulus values increased and depending on the increase in temperature, loss modulus changes was observed. For measurement of coagulation temperature, the rheometer was used in oscillation mode. The coagulation temperature was determined by extrapolating the rapidly rising storage modulus (G') to intercept the temperature. Egg white loses its fluidity around 60°C. The thermogram of egg white shows 2 major endotherms at 65°C and 80 to 85°C, corresponding respectively to the denaturation temperatures of ovotransferrin and ovalbumin [21].

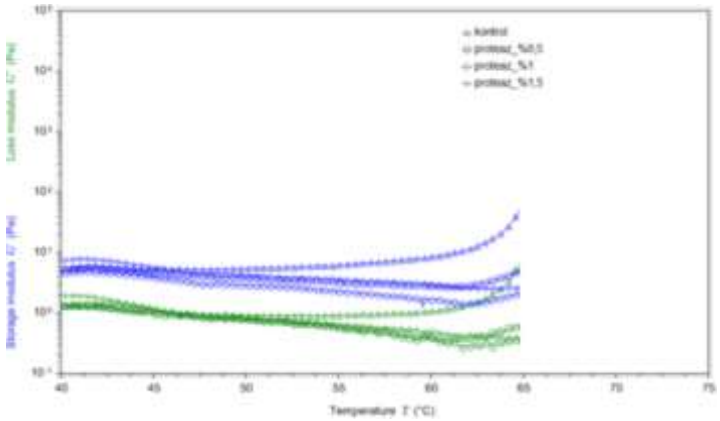

Figure 4. Temperature scanning curve of examples protease enzyme modified liquid egg whites

CONCLUSION

The results indicated that treatment of egg albumen with protease enzyme significantly modified its rheological behaviours to help provide an improved better taste and texture to produce processed dry egg products, processed value added liquid egg products and specialty egg products. This emphasizes the measurements and conclusions of analysed parameters during enzyme treatment are important in designing of fermentor for egg processing. However, further investigations of the structure of enzyme on the egg's functionality are required to clarify. Protease enzyme has potential to become significant breakthrough in the industry and in preserving egg proteins deformation during processing stages. As a result of this study, enzyme modified LEW's rheological properties was concluded that the enzyme concentration rate is important to determine the process conditions and in terms of quality control criteria's in egg processing plants. At the end of the study; determining the rheological properties of

enzyme modified egg whites, information, which can be used, in particular in egg processing industry has been reached. It was concluded that protease enzyme is useful for improving the stability of egg-white proteins during storage. Enzyme treatments may be used to reduce adverse effects of heat, egg yolk contamination. Protease may also be used in egg powder processing to increase functional properties of egg white powder.

ACKNOWLEDGEMNETS

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PASTING PROPERTIES OF HIGH AMYLOSE STARCH AT VARIOUS PROCESS CONDITIONS

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ABSTRACT

Starch is a food ingredient used in many food products as a thickener, texture improver and stabilizer, which are achieved by pasting and gelling properties of the starches. Technological properties of starches are mainly depend on molecular composition of starch. In addition, process conditions such as stirring rate and heating/cooling rate also affected the quality of starch-included product as well as pasting properties of the starch. Therefore, in the present study, the effect of process conditions on the pasting properties of the 70% high amylose corn starch was determined by using as stress/strain controlled rheometer. These starch properties were the peak viscosity, pasting temperature, holding strength, breakdown viscosity and final viscosity calculated along with the accompanying software. The starch suspensions (14%, w/w, dsb) were heated at 10°C/min and 5°C/min while being stirred at 50 rpm, 160 rpm and 250 rpm levels. According to the results, generally both heating rate and stirring rate considerably affected the pasting properties. When stirring speed increased from 50 rpm to 250 rpm, peak viscosity of starch suspension decreased. When cooking rate decreased from 10°C /min to 5°C /min at all stirring speed, the pasting properties except pasting temperature and holding strength dramatically decreased. The highest value for holding strength was obtained at 50 rpm, 5°C /min. The findings of the present study highlighted that process conditions should be considered during production of the food products including starch to obtain the products with desired quality.

Key Words: *corn starch, amylose, process conditions, pasting properties*

TEXTURE MODIFIED PROTEIN-BASED BEVERAGES FOR ELDERLY PEOPLE WITH OROPHARYNGEAL DYSPHAGIA

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ABSTRACT

Oropharyngeal dysphagia (OD) is a symptom, commonly found in the elderly and defined as a difficulty or inability to swallow thin fluid foods. Such physical disorder may contribute to malnutrition due to the limited food and liquid intake. The effective treatment of dysphagia requires that fluid foods are consistently prepared with the correct viscosity. On the other hand, increasing the protein content in food is an effective way for the prevalence of malnutrition. Recent studies have proposed new concepts such as the ‘‘slow vs. fast’’ protein concept based on the speed of protein digestion which is a limiting factor for the loss of muscle mass. The aim of this study was to design texture-modified protein-based beverages for elderly people with OD and to explore in vitro the digestibility of food proteins in the gastrointestinal tract. The texture of protein based beverages was designed by changing protein (egg, milk and pea) concentration and/or adding polysaccharide Konjac glucomannan. Following the National Dysphagia Diet guideline the beverages were categorized according to the viscosity into groups of thin (1–50 cP), nectar-thick (51–350 cP) and honey-thick (351–1750 cP) foodstuffs. The viscosity was measured by shear rate for swallowing of. The digestibility of proteins was defined by the content of peptides and free amino acids that is released from beverages in the gastrointestinal tract and thus becomes available for the intestinal absorption. In vitro digestion method proposed by INFOGEST was used to simulate the conditions in gastrointestinal tract.

During in vitro digestion of beverages, the pea proteins have been digested faster than milk and egg proteins. The free amino acids profiles obtained after digestion of pea, egg and milk proteins were in agreement with the results about nitrogen content in the gastrointestinal fluids. Moreover, the beverages with higher protein content showed a lower rate of hydrolysis. It was found that the addition of Konjac glucomannan to the protein-based beverages may decrease the rate of proteolysis during gastrointestinal digestion.

Key Words: *texture, proteins, konjac glucomannan, digestion speed*

QUALITY CHARACTERISTICS OF WHIPPED CREAM: EFFECT OF PROCESS PARAMETERS

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ABSTRACT

Vegetable whipping creams (VWC) are stable liquid oil-in-water emulsions, which can form a solid foam after whipping. The foam is stabilized by adsorbed proteins and low molecular weight emulsifiers. Whipped creams are widely used in pastry industry. Considered quality attributes of the VWC are textural properties, overrun, foam stability during storage as well as the sensory properties such as taste and color. In the present study, the effect of process conditions (whipping temperature (4 and 25ºC) and whipping time) on the density, overrun and firmness parameters of the cream were investigated. The overrun value of VWC prepared at 4°C was found to be 205.90% whereas it was 60.95% for VWC prepared at 25°C. This difference might have resulted from the action of protein displacement and the formation of crystalline fat globules, which can affect the foaming mechanism. VWC prepared at 4°C had the more acceptable overrun and firmness values when compared with the sample whipped at 25°C. The firmness value of VWC prepared at 4°C and 25°C was measured as 259.81 g and 26.24 g, respectively. When excessive whipping time was applied, the overrun was found to be too low due to the loss of structure. For instance, the overrun value of VWC prepared at 4°C decreased from 205.90% to 141.84% as the whipping time was increased. The same results could be observed when the whipping temperature was increased for VWC. In the meantime, the textural properties were not desirable that might be due to the extensive fat partial coalescence that does not provide semi-solid structure anymore. These fundamental results demonstrated that the whipping temperature of VWC is important for the protein replacement and the formation of fat crystals. The results of the present study indicated that production process should be optimized considering quality characteristics of the whipping cream.

Key Words: *vegetable whipping cream, texture, process*

TEXTURAL PROPERTIES OF HOUSEHOLD TYPE GLUTEN-FREE BREADS

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ABSTRACT

Celiac disease (CD) is an autoimmune intestinal disorder that induced by some grains (wheat, barley, and rye) which include "Prolamin" proteins (gliadin, hordein, secalin). The most common symptoms of CD are malnutrition, weight loss, diarrhea, anemia, abdominal pain, and constipation. The only cure for celiac patients to avoid these symptoms is a lifelong gluten free diet. Gluten is a combination of gliadin and glutenin proteins that are responsible for the viscoelastic properties, gas holding capacity and structure building of the dough. The absence of gluten in the structure results in a quality loss in the finished product as low volume, quick staling, and easy friability. Therefore, especially hydrocolloids, emulsifiers and protein-based ingredients are using to enhance quality parameters of gluten-free bakery products by imitating features of gluten. However, bread is a staple food and widely consumed bakery product in the world, there are scarcely any studies available to assess textural properties of household type gluten-free breads (GFB). Studies have to focus on enhancing GFB formulations that can be easily produced and freshly consumed in the houses by using bread making machine for who suffer from celiac disease. In a study, it was examined that the effects of protease treatment on quality of rice flour based gluten-free breads. In this regard, protease treatment was applied with four different commercial proteases which were obtained from different sources as *Aspergillus oryzae*, *A. melleus* and *Bacillus stearothermophilus*. GFB were produced by using a household type commercial bread maker and evaluated the effects of protease treatment on the crumb texture. Moreover crumb texture was associated with staling degree. For this reason, GFB were stored at 25°C for three days. According to results, the crumb hardness values were differ between 0.34-2.02 N. In general terms, it was concluded that protease treatment improved the quality of GFB by decreasing crumb hardness and staling rate.

Key Words: *gluten-free, bread, household type, texture*

TEXTURAL PROPERTIES OF RICE FLOUR BASED GLUTEN FREE CAKES

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ABSTRACT

Celiac disease (CD), in other words, coeliac disease or celiac sprue, is a genetic autoimmune intestinal disorder whose prevalence is approximately 1% of the population in the world. CD is caused by prolamin fractions of cereal grains as gliadin, hordein, secalin, and avenin, for wheat, barley, rye, and oat, respectively. The most common symptoms are vitamin and mineral deficiencies because of malabsorption depending upon damages in villus mucose, weight loss, anemia, diarrhea, and osteoporosis. The only accepted and applied treatment is a strict adherence to gluten-free diet (GFD) throughout their life. In GFD, the people who suffer from celiac disease have to consume naturally glüten-free grains (rice, maize, millet, teff, sorghum), pseudo-cereals (amaranth, buckwheat, quinoa), legumes (chickpeas, bean, lentil), nuts (hazelnut, almond, chestnut, cashew nut) and tubers (potato, tapioca, arrowroot) based cereal products. However, glüten-free products have a weak structure due to lack of gluten. Therefore, some additives particularly hydrocolloids (gums) and emulsifiers are using to enhance textural properties and thereby evaluate sensory properties of gluten-free products by mimicking the viscoelastic features of gluten. To evaluate these properties, there is a contemporary method, which name is Texture Profile Analysis (TPA). The most common parameters are hardness (firmness), cohesiveness, gumminess, resilience, and springiness that usually measure to characterize glüten-free cakes by using TPA. Researchers worked on the influence of four different protein sources (pea, rice, egg white, whey) on the textural characteristics (hardness, springiness, cohesiveness) of rice flour-based gluten-free layer cakes. In this regard, vegetal proteins decreased the springiness and cohesiveness values when compared with control cakes while animal proteins increased hardness, particularly egg white protein in spite of augmenting specific volume. In another current study, it was examined that effects of using three different concentrations (4, 8 and 12%) cowpea protein isolate (CPI) on textural properties (firmness, springiness, cohesiveness, and chewiness) of glüten-free rice muffins. According to this study, increasing of CPI concentration lead to increase firmness values when comparing with the control sample and utilizing above 8% level of CPI caused higher springiness and cohesiveness levels. Also, they suggested that using protein sources could make way for less crumbly and spongier cakes.

Key Words: *gluten-free, cake, rice flour, texture*

EFFECTS OF PSEUDOCEREALS ON TEXTURAL PROPERTIES OF GLUTEN-FREE BISCUITS

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ABSTRACT

Celiac disease (CD) is a genetic intestinal autoimmune disease characterized by life-long intolerance to materials such as prolamins in wheat, barley, rye, and oats. Consumption of gluten and similar proteins can damage villus mucose which causes abdominal bloating and pain, fatigue, chronic diarrhea, weight loss and failure-grow in infants and the malabsorption of essential nutrients (calcium, iron, vitamins like A, D, E, K, and folate). The only treatment for CD is life-long adherence to a strict gluten-free diet (GFD). Gluten-free flour (GFF) formulations can be composed of brown or white rice, millets, sorghum, maize, soy, chickpea, tapioca flour, potato flour, hazelnut, chestnut, pseudo-cereals like amaranth, buckwheat and quinoa. Among them, pseudo-cereals, in other words, non-cereal grains are not only an alternative of GFF but also have a rich nutrition profile especially content of protein, unsaturated fats, micronutrients, dietary fibers and bioactive components. Moreover, emulsifiers and hydrocolloids have the ability to imitate the viscoelastic properties of gluten. Therefore, utilizing a combination of GFF and these additives improve the textural properties and appearance of the final products. Texture Profile Analysis (TPA) method are used to measure textural features. The most common parameters measured using TPA in biscuits are hardness and fracturability/brittleness. Researchers studied the influence in textural features (hardness and fracturability) of buckwheat flour and carboxymethyl cellulose (CMC) on the manufacture of gluten-free cookie dough of acceptable rheological features. In the present study, results of the physical and sensory evaluation of gluten-free cookies revealed that buckwheat addition led to a decrease in cookie hardness and fracturability. In another study, it was evaluated influence in textural features (hardness) of quinoa flour (QF) instead of wheat flour (WF) in gluten-free cookies. In this study, the hardness values of cookies increased the addition of QF instead of WF. The gluten free cookies including the highest QF (50%) possessed the hardness values above the other formulations. The lowest hardness values were determined for gluten-free cookies made with 100% WF (control group).

Key words: *pseudo-cereal, gluten-free, biscuit, texture*

EFFECT OF SOME LACTIC ACID BACTERIA ON THE TEXTURAL, RHEOLOGICAL AND QUALITY PROPERTIES OF SOURDOUGH BREADS

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ABSTRACT

Sourdough bread is a traditional product formed by interactions between lactic acid bacteria (LAB) and yeast. Lactic acid, acetic acid and volatile compounds such as alcohol, ester and carbonyl, which occur in the sourdough fermentation, are produced by microorganisms in the dough. It is known that the use of sourdoughs has more flavor, better rheology and storage properties than products obtained using commercial yeast. It is also known that physicochemical changes (staling etc.) and microbiological disorders (such as rop formation, mold growth) significantly reduce the shelf life of bread. In this study the proteolytic activity of 12 different LAB strains were determined. The proteolytic activity in the sourdough is produced by free amino acids. The best proteolytic activity in our study was found to have Lactobacillus brevis strains. Sourdough was prepared using different lactic acid bacteria and HM3 (S. pastorium) as yeast starter. The sugars obtained from the purification of EPSs from the sourdoughs were revealed by HPLC. The monosaccharides composed of EPS produced in the sourdough were determined to be glucose and fructose. The hardness values of the breads ranged from 2.44 to 7.26 N. The control (39LB2-28C1B3-HM3) sourdough bread reached the highest hardness value and sourdough breads showed higher hardness values than the sample produced by commercial yeast breads.

Keywords: *sourdough bread, LAB, proteolytic activity, rheology, texture*

THE EFFECT OF INCORPORATION OF OLEASTER (*Elaeagnus angustifolia L.*) POWDER ON RHEOLOGICAL AND TEXTURAL PROPERTIES OF WHEAT DOUGH AND BREAD

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ABSTRACT

Bakery products, especially bread, are the most common foods worldwide. Due to the variety of ingredients, different types, and high nutritional value, bread is one of the most commercially available products and often a primary product for consumers, who are nowadays more aware of the influence of diet on improvement of the quality of their lives and health. In Europe and Asia Oleaster (*Elaeagnus angustifolia* L.) has been used for centuries as food as well as for medicinal properties. Its fruits are rich source of dietary fibers, soluble sugars, essential oils, vitamins and minerals. In this study, oleaster was incorporated into wheat flour dough at different ratios (0, 5, 10 and 15%, w/w) in order to increase the nutritional properties especially dietary fiber content of bread. Rheological properties of dough and textural properties of the resulting bread were measured using farinograph-extensograph and texture profile analyzer apparatus, respectively. In the results, increase of oleaster level significantly (p<0.05) increased energy and resistance to extension values of the dough samples while significant (p<0.05) decreases in extensibility, water absorption and stability values of the doughs were observed. Addition of 5% of oleaster provided a (p<0.05) decrease in the hardness values of the bread. On the other hand, oleaster incorporation into the bread at higher levels caused significant (p<0.05) increase of hardness. In conclusion, oleaster (5% w/w) could be incorporated into bread as an ingredient in order to increase its nutritional properties without affecting its textural properties.

Key Words: *oleaster, bread, texture, dough rheology*

RHEOLOGICAL AND QUALITY CHARACTERISTICS OF WHEAT BREAD ENRICHED WITH CAROB FLOUR

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ABSTRACT

Carob flour (CF) has good nutritional value due to having high content of various bioactive compounds such as fibres and phytochemicals. Additionally, low fat content of CF is generally considered as a healty ingredient. The aim of this study was to determine the effect of CF addition (0, 2, 4, 6, 8 and 12%) in wheat bread formulation in terms of rheological and quality characteristics. According to results obtaining from farinograph and extensograph measurements, CF addition increased the development time (min), stability (min) and resistance to extension of wheat dough while decreasing the extensibility as significantly (p<0.05). Energy (cm^2) of the dough samples also decreased with the increasing level of CF addition. As for the bread quality characteristics, CF substitution with wheat flour at increasing level reduced spesific volume (mL) and increased the hardness value (N) of breads (p<0.05). This can be due to the effect of gluten dilution of the bread formulations. This study showed that low-level addition of CF (2% and 4%) gave similar breads with control (0% CF) in terms of hardness and spesific volume. The breads containing 2% and 4% CF were also acceptable breads in the sensory analyses.

Key Words: *wheat flour, carob flour, rheology, bread quality*

RHEOLOGICAL PROPERTIES OF SOURDOUGH FERMENTED WITH DIFFERENT LACTIC ACID BACTERIA STRAINS

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ABSTRACT

Sourdough is defined as a mixture of mainly cereal flour and water, which is made by lactic acid bacteria (LAB) and yeasts, either by spontaneous fermentation or by fermentation initiated through the addition of a sourdough starter culture. The use of lactic acid bacteria in sourdough preparation of wheat breads is well documented. There is considerable consensus with regard to the positive effects on the product by its use, including improvements in bread volume and crumb structure. In our study two LAB strains isolated from sourdough, *Lactobacillus brevis* and *Lactobacillus plantarum* coded as HEB33 and ELB78 respectively, and their combination were used in sourdough preperation and fermented at 30°C. At the same time a sourdough fermented spontaneously at the same temperature. Dough rheology was analyzed after preparing the bread dough including the sourdough at 30% level. Frequency sweep test was conducted between 0.628 and 62.8 rad/s at 25°C. Storage modulus (G'), loss modulus (G''), and complex modulus (G^*) were determined using parallel plate system with 1 mm gap at 25°C. Generally sourdough bread dough fermented spontaneously had much lower G' and G'' value compared to other dough fermented with strains. No significant differences were observed between the doughs fermented with *Lactobacillus plantarum* and *Lactobacillus brevis*. As a result, both strain of L.brevis and L.plantarum had positive effect on sourdough rheology.

Key Words: *sourdough, dough rheology, lactic acid bacteria*

USAGE OF SUGAR MOLASSES IN THE ICE CREAM FORMULATION INSTEAD OF SUGAR

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ABSTRACT

In the food industry, 33-50% of foods are wasted throughout food supply chain. The evaluation of food wastes is very important for economic purposes; therefore, it is one of the main attractive area in the food industry. One of the food wastes is sugar beet molasses arised during sugar production. Molasses is composed of high content of fermentable sugars (sucrose, glucose, fructose, raffinose) and different compounds such as a betaine, lactic acid, amino acids, minerals, vitamins and phenolic compounds. In this study, usage possibility of molasses in ice cream formulation instead of sugar was investigated. Ice cream is a colloidal food product that is consumed by people of all ages. It contains air bubbles, fat globules, ice crystals, unfrozen serum phase, sweeteners, stabilizers, casein micelles, and proteins. Sugar beet molasses, an important industrial food waste, was used as sugar substitute in ice cream formulation in concentration ranged between %0 and 100% and the rheological properties of the produced ice cream mixes was determined. It was found that sugar beet molasses added to ice cream significantly affected all rheological parameters of ice cream sample. The apparent viscosity decreased with shear rate, indicating shear thinning behaviour of the samples. Ostwald de Waele model well described the flow behaviour of the ice cream samples with R^2 values changed between 0.96 and 0.99. Consistency coefficient (K) and flow behaviour index (n) values were in the range of 5.69–1.03 Pa.s^n and 0.65–0.44, respectively. K values increased with increasing molasses concentration in the formulation. The results of the present study showed that molasses can be used in the ice cream formulation as a partial replacer of sugar.

Key Words: *ice cream, food waste, rheology, molasses, sugar*

FOOD GROUPS: CONFECTIONARY PP-32

RHEOLOGICAL PROPERTIES OF JELLY PRODUCED BY MOLASSES AS AN ALTERNATIVE TO SUGAR

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ABSTRACT

The aim of this study is to investigate the rheological characteristics of jelly samples produced with different gelatin concentrations (5.0, 7.5 and 10.0 %) and molasses varieties (grape, mulberry and carob) instead of sugar as a healthier alternative in the production of sugar-free jelly. In order to healthier jelly production, cold production methods have been preferred to prevent HMF formation. Rheology is considered as a sophisticated and powerful tool to investigate the viscoelastic behavior and sol-gel transition of food gels. Steady shear rheological measurements to determine flow behavior and temperature dependency of G' and G'' (storage and loss modulus) values of jelly samples to measure sol/gel transition temperatures were performed. Ostwald de Waele was found to be the best model to describe the flow behavior of the jelly samples. Grape based samples had the highest apparent viscosity (η_{app}) and consistency coefficient (K) values while mulberry was the lowest. These values of jelly samples increased with increasing gelatin concentration, as expected. The concentration dependency of these values exhibited following trend: grape>mulberry>carob. In jelly samples, the gelation temperature ranged from 20 to 29°C, while the melting temperature ranged from 33 to 39°C. Among the molasses, the lower gelation temperature and higher melting temperature, namely higher ΔT was observed for grape samples which had melting temperature higher than body temperature at the 7.5 and 10% gelatin usage. Melting and gelation temperatures increased in direct proportion to the gelatin concentration in the formulation. The study has a potential to increase the consumption of molasses, which has high natural sugar and mineral content, and reduce the intake of excess sugar due to the consumption of confectionery especially among children.

Keywords: *molasses, sugar-free jelly, rheology*

GELATINE ALTERNATIVES IN JELLY-TYPE CONFECTIONERY PRODUCTS

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ABSTRACT

The formulation of jelly is composed of water, glucose syrup, sugar and thickener ingredients. Thickeners are the key ingredients of this class confectionery to manufacture the end products with desired quality. Among thickener ingredients, gelatine is widely used one. Gelatin is produced by hydrolysis of collagen obtained from animal skin, white connective tissue and bones. Gelatin gels melt at relatively low temperature (melt-in mouth), and they are slow-setting. The structure of the products produced with the gelatin varies depending on the percentage of gelatin used and the degree of bloom. In addition gelatin, being a protein, is highly sensitive to thermal and high acidic treatment. Although it has unique characteristics, there are concerns for about usage of gelatin due to its animal-based source. The usage of gelatin from porcine/bovine is problem for the vegetarian, halal and kosher markets. Therefore, alternative gelatin thickeners have been studied for many years. For this aim, starch, pectin, agar-agar, xanthan gum, gum arabic and carrageenan were investigated. The most commonly alternative ones used in jelly production are starch and pectin. As pectin is obtained from apple pomace or citrus peels, starch is obtained from potatoes and cereals. Pectins due to their various possibilities of application and their technological advantages are becoming more important as texturizing gelling agents and thickeners in the confectionery. Starch is the most commonly used thickener due to its suitable cost and abundant presence. In contrast to gelatin, pectins are standardized to constant gelling strength, they dissolve rapidly and they are heat-resistant even with low pH values. Pectins allow sufficient time for depositing but at the same time set relatively quickly. After a relatively short standing time the products can be processed quickly. Jellies made with pectins are furthermore distinguished by a unique texture which can be determined individually. This texture ranges from firm and elastic to smooth. Starch is high temperature resistant raw materials. The textural properties vary depending on the modified and/or unmodified starch in jellies. While pectin and starch provide a cutable structure, the gelatin provides a chewable structure, which can be achieved by combining different thickeners.

Key Words: *gelatin alternatives, confectionery, thickeners*

FOOD GROUPS: CONFECTIONARY PP-34

VISCOELASTIC PROPERTIES OF LOW CALORIE SAFFRON DESSERTS FORMULATED WITH THREE TYPES OF IRANIAN TRAGACANTH GUM

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ABSTRACT

The aim of this study was to investigate the viscoelastic properties of low calorie dairy desserts formulated with three gum tragacanth (GT) species. Using the Design Expert software, 17 dessert samples were produced. Fixed component of the samples consisted of milk powder (9% w/w), saffron powder (0.02% w/w), rosewater (3% w/w) and stevia (0.02% w/w). The hydrocolloid part of the samples composed of *A. gossypinus*, *A. fluccosus*, and *A. rahensis*. Results of the present study showed that the sample with the highest amount of A. *gossypinus* showed the strongest structure in frequency and strain sweep tests. On the other hand, mixture of *A. rahensis* and *A. fluccosus* had the lowest structural strength. Samples with *A. gossypinus* and *A. gossypinus* and *A. fluccosus* which showed the highest constant (*a*) values of the Power law model equation ($G' = a\omega^b$) and the highest sensory evaluation scores. Our results also revealed that there was no significant difference between sensory score of two market samples and the sample with the highest amount of A. *gossypinus.* Based on some reports about the prebiotic properties of GT, the findings of this study could be helpful in developing new prebiotic dairy desserts.

Key Words: *gum tragacanth, dairy dessert, viscoelastic properties, frequency sweep*

THE EFFECT OF DIFFERENT ANIMAL MILK ON RHEOLOGICAL CHARACTERISTICS OF DAIRY PRODUCTS

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ABSTRACT

Rheological properties of dairy products are an important parameter to determine the quality of the product and the consumer's acceptance. Dairy products have complex matrix, thus, their rheological properties have been influenced by some factors such as milk type, ingredients and manufacturing/storage conditions. Knowledge of milk type used in production is important for whether the products display any of the physical, chemical or sensory characteristics that are unacceptable for consumption. In this context, the aim of this review was to overview the effect of different animal milk origin on rheological and structural characteristics of dairy products.

Key Words: *rheology, different animal milk*

INTRODUCTION

The word “rheology is derived from the Greek *rheo* (to flow) and *logos* (science), which describes the flow characteristics of liquids and the deformation of solids by using mechanical forces. Rheology determines the characteristics of both solid and liquid foods, while viscosity is used to describe the rheology of fluid foods and texture charcaterizes the rheological and structural (geometric and surface) attributes of solid food.

Table 1. Test for measurements of textural or rheological characteristics

Tests	Mesurements	Instrument used	Measurement parameters
Empirical	Puncture Force	Texture Measuring System	Puncture characteristics
	Compression	Texture Measuring System	Peak force, firmness, compression energy
Imitative	Texture Profile Analysis	Texturometer, Texture Profile Analysis Torsion Gelometry	Hardness, brittleness, adhesiveness, springiness, cohesiveness, gummines, chewiness, resilience, fructurability
Fundamental	Compression	Texture Measuring System	Modulus of elasticity, Poission’s ratio
	Stress Relaxation	Texture Measuring System	Residual stress, relaxation time
	Creep	Controlled Stress Rheometer	Shear modulus, creep compliance
	Oscillation	Controlled Stress Rheometer	Storage modulus(G'), Loss modulus (G''), Phase angle, Complex modulus and viscosity

Rheology has been thought as an important analytical measurement (Table 1) to design manufacturing processes, monitore quality of food products, develop novel foods and determine consumers' attitude and acceptance [1-5].

In dairy industry, the rheological parameters are determinant factors for designing and evaluation of the processing equipment, process parameters, adjustment of time x temperature x flow rate selection of fluid products, development of novel products, consumer acceptability and elucidation of the relationship among structure and textural properties. The rheological and textural properties of dairy products consisting of mixtures of solids and/or fluid are determined by measuring force and deformation as a function of time. Rheological behavior of dairy products can be influenced by (i) milk quality, (ii) milk type, (iii) additives, (iv) manufacturing process, and (v) post-manufacturing process [2, 6].

Since the breed, stage of lactation, milking season and feeding affect milk composition and buffering capacity, texture and rheology of the final product is directly dependent on the composition (Table 2.) and origin of milk. For example, viscosity of goat milk was 2.12 cPas, 2.48 cPas for sheep, 2.8 cPas for camels, 2.2 cPas for buffaloes and 1.7 cPas for cows.

Table 2. The composition of different animal milk

g kg^{-1}	Ruminant					Non-ruminant		
	Cow	Buffalo	Goat	Sheep	Camel	Horse	Donkey	Human
Total solid	105-137	145-184	119-163	152-193	108-145	93-116	85-117	125
Protein	29-50	7-50	25-51	50-65	30-50	14-34	14-22	8-15
Fat	25-60	61-96	25-78	51-90	26-67	5-47	1-18	22-52
Lactose	36-55	44-52	39-63	37-55	31-58	56-72	58-74	60-90
Ash	6-9	7-9	7-11	7-10	6-10	3-5	4-5	2-3

The highest value for viscosity was exhibited by ovine milk, followed by caprine, bovine and camel milks. For bovine, ovine and caprine milk, three different transient viscosity stages were identified and described by mathematical expressions, whereas camel milk showed no significant variation in viscosity during gelation. The chemical composition of milk, namely total solids and protein content, had a major effect on the rheological properties of the curd. A power law model allows the determination of the flow behaviour index and the consistency coefficient of curd made from different milk sources [7].

Goat milk products present lower hardness, adhesiveness, consistency, stability and extrusion force with a high tendency to syneresis than cow and sheep milk products. Park [8] stated that Labneh displayed highest viscosity for sheep milk followed by goat's, cow's, and camel's due to higher solid contents [2, 8-10].

Bezerra et al. [11] investigated different formulations of yogurt from buffalo and goats milk. They determined that the yogurt made only from goat milk showed lower shear stress because of typical soft coagulum.

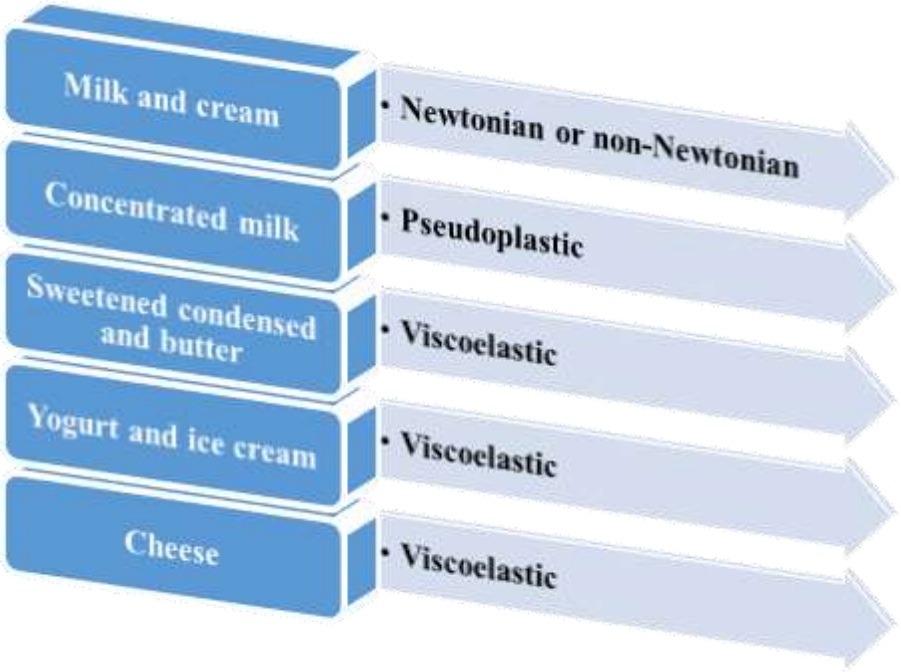

Figure 1. Rheological behaviors of milk and milk products [2]

Hanif et al. [9] studied effect of storage on rheological and sensory characteristics of cow and buffalo milk yogurt. They reported that means for viscosity, flavor, texture, appearance and taste decreased while firmness increased during storage. Buffalo milk yogurt showed better rheological properties (viscosity and firmness) and sensory characteristics than cow milk yogurt. Yogurt from cow milk got higher score for texture and taste than buffalo yogurt while flavor and appearance of buffalo was better [9]. Nguyen et al. [12] mentioned that buffalo yogurt had different rheological properties and microstructure than bovine yogurt. It exhibits a higher degree of syneresis and a greater degree of thixotropy and these defects correlate with a more porous microstructure that is disrupted by larger fat globules than in bovine yogurt [12]. Nguyen et al. [13] reported that buffalo and bovine yogurts differ in their microstructure and physicochemical properties, following fermentation and during cold storage. Buffalo yogurt exhibited a weaker network structure that was more porous, irregular and disrupted by large unhomogenised fat globules. This difference in microstructure led to a significantly higher degree of syneresis, a greater degree of thixotropy, a greater consistency coefficient (*K*) and a smaller value of flow behaviour index (*n*).

Miocinovic et al. [14] reported that gelation and fermentation times of goat milk yogurt were longer, while gelation pH, storage moduli (G') and yield stress values were lower, compared with those of cow milk. Textural properties of goat milk yogurts such as firmness, consistency, cohesiveness and viscosity index were very poor. Goat milk yogurt could not be classified as a set type product because of its very low values for G', yield stress and all textural attributes.

Yilmaz-Ersan et al. [15] reported that buffalo milk yogurt had the higher levels of texture parameters (firmness, consistency, cohesiveness, and index of viscosity) than cow and mixed milk yogurt. It could be related to the higher levels of protein and total solids in buffalo milk. The level of fat in Cheddar

cheese matrix made from goat's milk had been shown to be more influential on the rheological properties than a protein consisting mainly of β-casein [16].

Zedan [17] studied the evaluation of Mozzarella cheese from different milk types. The cow milk Mozzarella cheese tended to be softer, slightly better in flexibility and contained slightly higher moisture, fat and salt contents whereas buffalo milk Mozzarella cheese had higher protein content. Also cow milk cheese gained the highest score for organoleptic properties, while buffalo milk cheese showed the lowest quality. Mixing cow milk with buffalo milk highly improved the quality of the cheese.

Qadeer et al. [18] mentioned that based on the texture of camel milk cheese, the blend containing 10% buffalo was selected for the cheese as the higher levels resulted in high firmness, which was not the characteristic of camel milk cheese.

CONCLUSION

Rheological characteristics are important factors to design dairy processing and assure the quality of the final product. The quality, composition and type of milk, characteristics of additives and the technological process affect directly rheological properties of dairy products. As the composition and type of milk are the determinant factors on the rheological characteristics, in this concept further research should be carried out.

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TEXTURAL ATTRIBUTES OF WHITE CHEESES: CORRELATION WITH INSTRUMENTAL AND SENSORY MEASUREMENTS

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ABSTRACT

This study evaluated the correlation of instrumental and sensory textural attributes of full-fat white cheeses made from different milk origin (cow, sheep and goat). Quantitative descriptive analysis (QDA) and multidimensional scaling (MDS) texture maps showed differentiation of visual and instrumental assessment of cheese attributes. When the results are compared, it could be concluded that the change of textural properties of cheeses were significantly different. By the way high linear correlations were found between sensory and instrumental texture profile analysis (TPA) parameters for hardness, adhesiveness and gumminess and sensory fracturability. No significant correlations were found between sensory and instrumental TPA parameters for springiness and cohesiveness.

Keywords: *cheese, texture, sensory*

INTRODUCTION

Texture is one of the important attributes used for design of new food product and to assess product quality and acceptability by using descriptive sensory (subjective) or instrumental (objective) analyses [1, 2]. By the way, rheological measurements do not explain the complex aspects of texture experienced by humans due to the related dynamic nature of processes of breathing, chewing, salivation, swallowing, temperature changes, and tongue movements [3, 4]. In comparison with instrumental methods, sensory evaluations provide a more immediate measure of human perception [5]. However, instrumental measurements are considered to be more accurate than sensory analysis [6, 7, 8, and 9].

White cheese is one of the most famous Turkish cheeses which is manufactured originally from raw or pasteurized sheep, goat, cow milk, or a combination of these milks. It is a semi-soft, brined cheese variety with a slightly acidic and salty taste [10]. The aims of this investigation were to (a) characterize sensorially and instrumentally the texture of white cheese using TPA and multidimensional scaling (MDS) spatial mapping, (b) to study the influence of raw milk type (cow, sheep and goat) on the texture (sensory and instrumental) of cheese.

MATERIALS and METHODS

Material

Thirty different white cheese samples were collected from various large supermarkets located in Bursa, Turkey. The collected samples were immediately stored in the *original store* packages at 0-4°C until they are used. Cow (sample no 1-10) goat (sample no 11-20) and sheep (sample no 21-30) semi-hard, ripened cheeses were used for the sensory and instrumental testing.

Method

Sensory Properties

The sensory evaluation was performed using a Quantitative Descriptive Analysis (QDA) and a trained panel (n=13) aged between 22 and 45 years, males and females with experience on cheeses made from cow, goat and sheep milk. In the first session, the samples were presented to the panelists in order to generate the texture descriptors. The consensus of the definitions of the descriptors generated by the panelists is shown in Table 1. In the second session, the intensities of the texture attributes were scored. The samples were served at 25°C on plastic containers, labeled with three-digit random numbers. Six cheese samples were evaluated in each session [11, 12].

Table 1. Sensory texture language of white cheeses

Description	Definition
Viscosity	*Perceived firmness of the sample evaluated in the mouth*
Saltiness	*Taste, basic taste typical of sodium chloride*
Hardness	*Amount of force required to completely bite the sample*
Fracturability (brittleness)	*Amount of fracturability in the sample after biting*
Springiness (elasticity)	*Total amount of recovery after press*
Cohesiveness	*Degree to which the chewed mass sticks together*
Adhesiveness	*Degree to which the chewed mass sticks to mouth surface*
Appearance	*General appearance of cheese*
Chewiness	*The length of time or the number of chews required to masticate a solid food to a state pending for swallowing*
Gumminess	*A denseness that persists throughout mastication, the energy required to disintegrate a food to a state ready for swallowing*

Instrumental Texture Profile Analysis (TPA)

The evaluation of textural properties was conducted by using a texture analyzer TA-XT Plus (Stable Micro Systems) using a two bite compression (25% compression) of cylindrical samples in 36 mm of diameter as described by Gutierrez-Mendez et al. [13]. The cheese samples were carefully cut into pieces (45 mm diameter x 45 mm height) with a cheese slicer. After being cut, samples were left at room temperature (20°C) for 20 min prior to testing and the measurements were conducted in triplicate. Attributes measured were hardness, adhesiveness, cohesiveness, gumminess, springiness, fracturability and chewiness.

Statistical Analysis

Analysis of variance with means separations using LSD procedures and multidimensional scaling (MDS) spatial mapping of cheeses were used to analyze descriptive data using the software SPSS 20 (SPSS Institute Inc., Chicago, IL) (P<0.05, 0.01).

RESULTS and DISCUSSION

Texture can be defined as the attribute of a cheese resulting from a combination of physical properties, including size, shape, nature and conformation of the constituent structural elements, that are perceived by a combination of the senses of touch (tactile texture), vision (visual texture) and hearing (auditory texture) [14, 15, 16].

The final perception of texture should be based on human sensory evaluation, while, instrumental measurement of food texture, which includes destructive and non-destructive methods, is also widely used in research and industry [17]. Correlation of instrumental analysis with sensory texture data was evaluated by correlation analysis (Table 2) and multidimensional scaling (MDS) mapping (Figure 1) on the correlation matrix (P<0.05, 0.01). The positive correlation between sensory and instrumental data was found between instrumental hardness and sensory viscosity (r = 0,613, P<0.01), saltiness (r = 0,482, P<0.01), fracturability (r = 0,632, P<0.01), hardness ((r = 0,446, P<0.05), gumminess ((r = 0,395, P<0.05), chewiness ((r = 0,375, P<0.05). Upreti et al. [18] reported that fat type, proteolysis degree during ripening, moisture content, and pH value of the cheese are also other important factors, which affect hardness values. Instrumental hardness and adhesiveness (saltiness (r = 0,455, P<0.05), fracturability (r = 0,558, P<0.01), adhesiveness (r = 0,554, P<0.01), springiness (r = 0,407, P<0.05), cohesiveness (r = 0,460, P<0.05), gumminess (r = 0,538, P<0.01)) were the highly correlated with sensory data.

Sensory chewiness was significantly positive correlated gumminess (r = 0,466, P<0.01) and chewiness (r = 0,444, P<0.05). No significant correlations were found and instrumental TPA parameters for springiness and cohesiveness were between sensory properties. Sensory fracturability and instrumental hardness had the highest positive correlation (r = 0,632, P<0.01) also significantly correlated positively with instrumental fracturability (r = 0,552, P<0.01), adhesiveness (r = 0,558, P<0.01), gumminess **(**r = 0,601, P<0.01). According to Foegeding et al. [2] fracture properties proved to be the most highly correlated with sensory texture.

Table 2. Correlation between the sensory and textural parameters of white cheeses

	Textural Parameters						
Sensory Properties	Fracturability	Hardness	Adhesiveness	Springiness	Cohesiveness	Gumminess	Chewiness
Appearance	-0,062	0,268	0,070	-0,065	-0,136	-0,107	-0,170
Viscosity	0,186	0,613**	0,278	-0,022	-0,304	0,230	0,115
Saltiness	0,380*	0,482**	0,455*	-0,236	0,158	0,531**	0,469**
Fracturability	0,552**	0,632**	0,558**	-0,222	-0,041	0,601**	0,424*
Hardness	0,202	0,446*	0,246	-0,171	-0,213	0,139	0,014
Adhesiveness	0,304	0,295	0,554**	-0,028	0,144	0,388*	0,368*
Springiness	0,105	0,166	0,407*	0,125	0,124	0,264	0,334
Cohesiveness	0,026	0,268	0,460*	0,010	0,277	0,215	0,218
Gumminess	0,266	0,395*	0,538**	-0,145	0,025	0,352	0,207
Chewiness	0,319	0,375*	0,391*	0,174	0,197	0,466**	0,444*

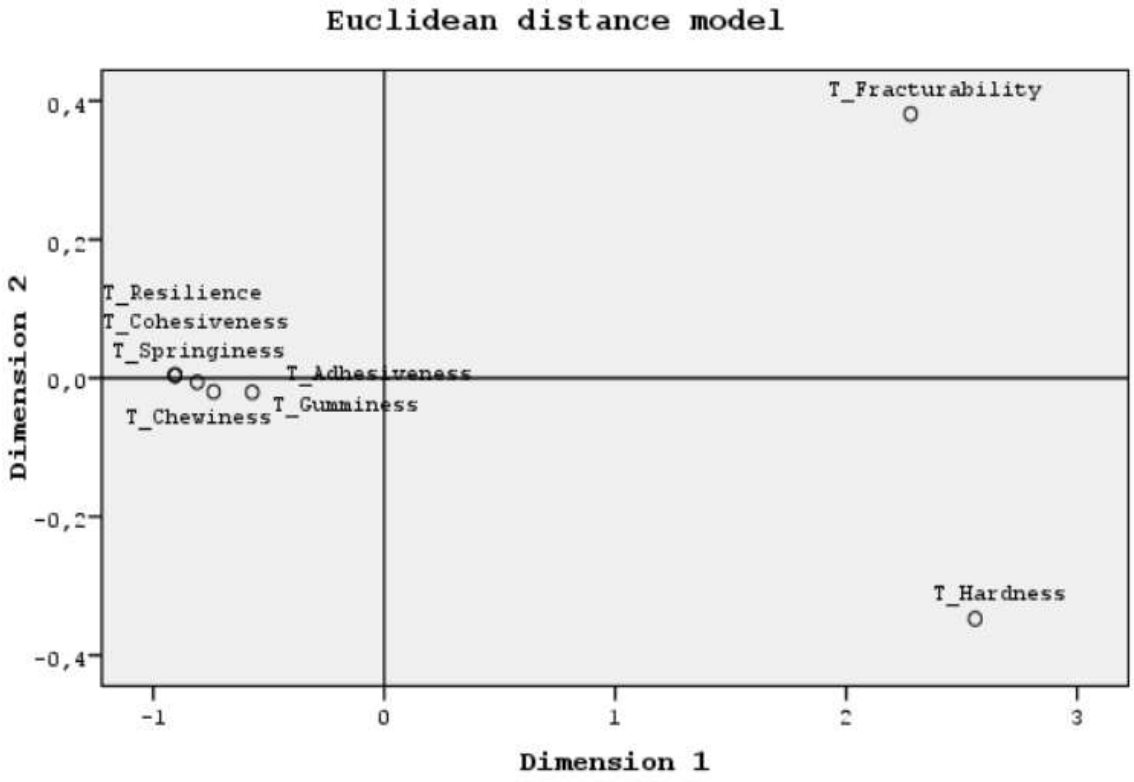
***Correlation is significant at the 0.01 level; *Correlation is significant at the 0.05 level*

Multidimensional scaling (MDS) was used to study qualitative relationships between different cheese samples and textural instrumental measurements *(*Figure 1a, b). Comparing the results, it could be concluded that the change of textural properties in goats, sheep and cow cheeses are significantly different due to the gel networks with different moisture content, the fat in dry mater, the pH as well as the total protein content. Pereira et al. [19] noted that sensory firmness and adhesiveness are satisfactorily correlated with the chemical data. Lawlor et al. [20] also reported that textural cohesiveness and firmness of cheeses were correlated to pH, acidity and the chemical composition. Upreti et al. [18], propose that the parameters of firmness, deformability and friability directly affect structure of cheese. In this study, sensory fracturability was linked to hardness, adhesiveness, gumminess and chewiness.

CONCLUSION

Texture is the quality attributed important for evaluation of product quality and acceptability. Correlating these results to sensory measures determined that sensory fracturability and instrumental hardness, adhesiveness, chewiness and gumminess were linearly more correlated with instrumental and sensory parameters. Significantly positive linear correlations between instrumental and sensory hardness have been found in white cheeses with varying raw milk (cow, goat and sheep) composition. Sensory properties and instrumental texture of white cheeses were affected by different milk composition, ripening period, manufacture processing leading to significant differences in the orally perceived thickness, hardness, saltiness, chewiness and fracturability. By the way, further studies should be carried out to study consumer's perception of cheeses with known differences in their formulation and to compare consumer and trained panelist texture perception of these products.

(a)



(b)

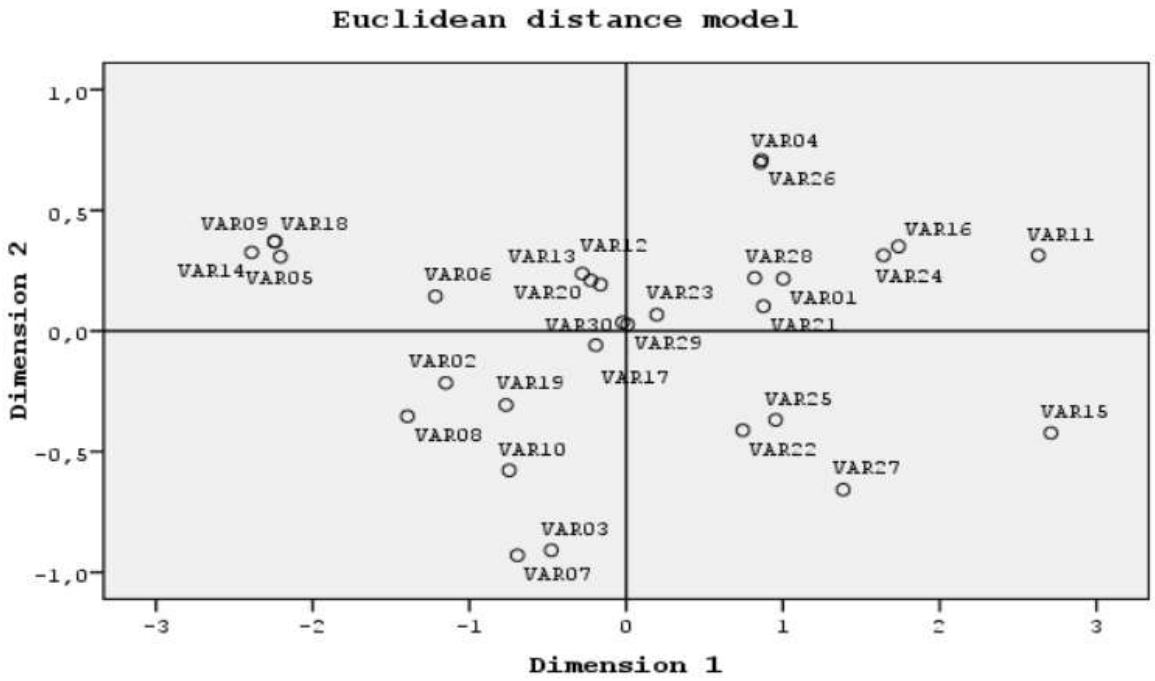


Figure 1. Multidimensional scaling (MDS) spatial mapping of cheeses for textural instrumental measurements (a) and for cheese samples (cow milk, 1-10; goat milk, 11-20 and sheep milk, 21-30) (b).

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COMPARISON OF RHEOLOGICAL PROPERTIES OF ICE CREAM PRODUCED WITH COMMERCIAL GUMS AND DEXTRANS

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ABSTRACT

Gums are products that have a wide range of uses in the food industry, which is modified or naturally produced. Gums are used in similar spreadable fruit products including jams, jellies, marmalades, traditional jams, traditional marmalades and low calorie products, dairy products and ice creams. Stabilizers are used in ice cream production. Salep is a stabilizer obtained from orchid ovules, which is difficult to produce and possesses high cost. Dextran, $(C_6H_{10}O_5)_n$ is a polysaccharide consisting of glucose monomers linked mainly (95%) by (1–6) bonds. Due to the potential of dextran for commercial, nutritional and health applications, it is widely used in chemical, food and pharmaceutical industries. In general, dextran is used as gelling, viscosifying, stabilizer, water-binding agent, prebiotic, bio-flocculant, cryoprotectant, texturising, and emulsifying agent in various food products. The aim of this study was to investigate whether dextran could be used as an alternative to these gums and salep because of the high cost of salep and other gums used in the ice cream industry. In this study, the rheology of dextran was compared with the gums used in the ice cream sector. Xanthan gum, guar gum, arabic gum and dextran were separately added to the determined ice cream formulations. The microorganisms used to produce dextran *Leuconostoc mesenteroides NRIC 1517* and *Leuconostoc mesenteroides KFRI-MG*. When the results of the analysis are examined, 2% by weight of dextrans (*Leuconostoc mesenteroides NRIC 1517* and *Leuconostoc mesenteroides KFRI-MG*), salep, arabic gum, xanthan gum and guar gum were added to the mixture of the ice cream formulation and compared. When the viscosity values are taken into account, the dextran samples have a lower viscosity than the xanthan gum and guar gum while having a higher viscosity than the arabic gum and salep. As a result of the analysis made, dextran was qualified from salep and arabic gum. When used in combination with xanthan and guar gum, it constitutes a strong gum.

Keyword: *rheology, dextran, gums, ice cream*

THE EFFECT OF BUFFALO MILK ON THE PHYSICAL QUALITY CHARACTERISTICS OF ICE CREAM

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ABSTRACT

Nowadays, ice cream is a popular frozen dairy product that is consumed in all seasons as milky sweet. The addition of different flavors, main components enhance the nutritional properties and the consumer acceptability of the ice cream. Milk kinds are very effective on the quality parameters of ice cream, which is the main component of ice cream making. In our study ice cream samples were produced using with buffalo milk, cow milk that was standardized to 7.10% with fresh cow milk cream and their mix. We examined on certain quality characteristics as first melting time, viscosity and overrun to see better the effect of buffalo milk on ice cream quality. First melting time giving information about the structure and it ranged from 1109 to 1510 seconds. According to results, the highest average melting time was found in buffalo milk with 1487 seconds, and the lowest first melting time was found in cow milk freezing with 1149.13 seconds. The volume increase values that affecting the freshness, yield of ice cream were detected highest (42.13%) in buffalo milk ice cream samples and the lowest (35.1%) in buffalo-cow milk ice cream. Viscosity values, which are the most important parameters in terms of consistency and air entrapment in ice cream samples, varied between 1440 and 6150 cP. The highest viscosity value was found in buffalo-cow milk ice cream with 4224.38 cP and the lowest viscosity value was found in cow milk ice cream trial sample with 1978.75 cP.

Key Words: *ice cream, buffalo milk, rheology*

IMPACT OF TEMPERATURE ABOVE 100˚C ON THE TEXTURAL CHARACTERISTICS OF DRIED APPLE

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ABSTRACT

Hot air drying is a common preservation process to prevent undesirable changes and deteriorate in fruits and simultaneously, increase shelf life and decrease transportation costs of products. However, removal of moisture from fresh fruits can change the textural characteristics and physical properties of products during drying. Therefore, to assess quality and acceptability of the dried fruits, optimization of drying operation is one of the key parameters in this industry. Meanwhile, mechanical measurements of product texture with instrumental analysis are cheaper than sensory analysis and present force-time and force-displacement data can apply for measuring hardness, fracturability, and crispness of dried fruits. In this research, circle shape apples (cv. Granny Smith) with 2 mm thickness and 20 mm diameter dried at laboratory convective dryer at temperatures 110, 115 and 120°C with the constant air velocity of 1.75 m/s. Drying test results were fitted with 6 drying models via a nonlinear regression analysis. Results of the statistical evaluation criteria indicated that the Midilli & Kucuk model was the best model to explain the drying behavior of apples. Also, Fick's second law of diffusion and a modified Arrhenius equation were used to estimating effective diffusivity and activation energy which, diffusion coefficients were varied from 2.36×10^{-9} to 2.64×10^{-9} m^2/s and activation energy was 13.69 kJ/kg.mol. The textural behavior of samples was characterized by using a TA-HD plus Texture Analyzer (Stable Micro Systems, UK) equipped with a 4 mm diameter probe (test speed of 1mm/s, trigger force of 10 g, depth of penetration 5mm). Also, a Texture Exponent Software program 32 was used to generate force (N)-time(s)-distance (mm) graphs. Hardness, fracturability, and crispness were varied from 2.69 to 4.69 N, 1.74 to 4.05 N and 5.31 to 9.84 N/mm, respectively. Also, maximum fracturability and crispness belonged to the sample dried at 120°C whereas, maximum hardness was shown by apples dried at 110°C. It was evident from the results that as drying temperature increased, hardness decreased and fracturability and crispness increased. These findings indicate that the texture changes at temperatures above 100°C can significantly improve fracturability and crispness of products which is desire properties for consumer acceptability.

Key words: *textural property, hardness, fracturability, crispness, drying kinetics, apple*

OPTIMIZATION OF NATURAL TENDERIZERS AND INVESTIGATION OF THEIR EFFECTS ON SENSORY AND TEXTURAL PROPERTIES OF BEEF, USING MIXTURE DESIGN METHODOLOGY

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ABSTRACT

Texture of food is one of the most important parameters especially in meat and meat products which have main role on mouth feel and consumer desirability. In this study, the effects of natural tenderizers (0-100% w/w) including Ginger extract, Kiwi extract, Onion extract, Lime juice and yoghurt on sensory and textural properties of grilled beef was investigated. Longissimus dorsi muscles were grilled after 24 hours tenderizing treatment. Physico-chemical properties, texture attributes and sensory characteristics considered as response variables. The quantitative relationship between the natural tenderizers as independent variables and the obtained response parameters fitted based on regression models. Based on responses, predicted model for firmness of treatments in Warner-Bratzler test was as below: (Firmness, Kilogram force) = -700 × Ginger - 1575 Kiwi - 75 Yoghurt - 325 Onion + 2675 Lime juice. This equation shows that using of Ginger, Kiwi, Yoghurt and Onion decreased while Lime extract increased firmness of treatments. The optimum conditions were found as 12.51% of Ginger extract, 25.28% of Kiwi extract, 44.9% of Onion extract, 4.3% of Lime extract, and 13% of yoghurt levels with 0.874 desirability function. These results were consistent with our sensory evaluation by 8 trained panelists. Industrial application of these natural tenderizers could be used for improvement of sensory and textural properties of meat and meat products.

Key Words: *texture, natural tenderizers, beef, optimization, D-optimal mixture design, sensory and textural properties*

EVALUATING TEXTURAL EFFECTS OF DIFFERENT HYDROCOLLOIDS IN "CEZERYE" PREPARED FROM QUINCE AND CORNELIAN CHERRY FRUITS

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ABSTRACT

"Cezerye" samples were produced using quince (*Cydonia oblonga*) and cornelian cherry fruit (*Cornus mas* L.) with different types of hydrocolloids (agar, carrageenan, locust bean gum, pectin and xanthan gum) at different concentrations (0.5, 2 and 4%). Agar, carrageenan and locust bean gum were used at 0.5% and 2% for quince "cezerye" production; while xanthan gum, pectin and locust bean gum were used at 2% and 4% for cornelian cherry "cezerye" production. Texture profile analyses were performed on final product. Results revealed that, hardness values significantly increased with increasing gum concentration regardless of gum type. In quince "cezerye", agar utilization caused the highest hardness values. The highest springiness value was 0.756, obtained from 0.5% carrageenan added sample. On contrary, no significant change was observed in springiness values of "cezerye" with cornelian cherry at various types and concentrations of gums. However, springiness values of quince "cezerye" were apparently affected by both different types and different concentrations of gums. Moreover, higher concentrations of gums generally caused higher chewiness and gumminess values. On the other hand, the highest hardness value was measured as 1689.169 g with locust bean gum when 2% of gum used in "cezerye" with cornelian cherry fruit. Among the samples including 4% of hydrocolloids, pectin utilization caused the highest hardness value (6214.82 g). In addition to hardness measurements, chewiness and gumminess values were also the highest in samples prepared with 2% of locust bean gum and 4% of pectin, respectively. According to overall results, it could be stated that utilization of different gums in production of "cezerye" from quince and cornelian cherry had generally positive effects on final product.

Key Words: *quince, cornelian cherry, cezerye, texture profile analysis, hydrocolloids*

TEXTURE PROFILE ANALYSIS OF CHOCOLATE COATED APRICOT PASTE CUBES PRODUCED FROM MALATYA APRICOTS

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ABSTRACT

Chocolate apricot or chocolate coated apricot paste cubes is obtained by coating of crushed sun dried apricot with chocolate. These products are preferred as Bitter Chocolate Apricot, Milky Chocolate Apricot and White Chocolate Apricot based on coated chocolate types. Nowadays, this new product, including exportable properties, is produced from sun dried apricot of traditional fruit of Malatya having Protected Geographical Indication (PGI) in the presence of Turkish Patent Institute (TPI) and European Union (EU) legistation. Especially, these chocolate products are economically provided the appreciation of discard apricots. There is no information on textural properties (TPA) of chocolate apricot or chocolate coated apricot paste cubes produced from Malatya dried apricot in the literature. TA.XT plus texture analyzer was used to perform the texture profile analysis (TPA) (36 mm diameter cylindrical and 100 mm compression platen probes), puncture test (PT) (2 mm diameter punch probe) and knife test (extended craft knife) of the all chocolate apricot or chocolate coated apricot paste cubes samples (n=3). These samples produced from different firms in Malatya. The toughness results of knife test changed from 1.69 to 2.15 kg whereas the work of shear data were 21.06 and 23.98 kg.mm. Texture profile analysis (TPA, hardness, springeness, cohesiveness, gumminess, chewiness and resilience) data among samples based on firms a remarkable differed whereas the highest hardness was 2396 (Firm 1, Milky) and the lowest chewiness 510.51 (Firm 2, Bitter) and the highest resilence 0.51 (Firm 2, Bitter). There was no fracturabilty and adhesiveness data for all samples.

Key words: *chocolate apricot, toughness results, texture profile analysis*

SOME PYHSICAL AND TEXTURAL PROPERTIES OF TEN DOMESTIC APRICOT CULTIVARS APPLIED TO NATURAL AND ARTICIFIAL DRYING METHODS

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ABSTRACT

Malatya alone has the share of 12% and 65% in world fresh and dried apricot production, respectively. The oldest written information on Malatya Apricot, having geographical indication (PGI) in the presence of Turkish Patent Institute and European Union regulation, is given in Evliya Çelebi's itinerary (about seven type [Red, Yellow, White, Müşmüş, Bey, Juicy, Pulpy]). In todays, although there are remarkable studies made on some physical and chemical properties of fresh or dried apricot of Malatya, there is no information on textural properties of Malatya dried apricot in literature. In this work, ten domestic apricot cultivar (Hacihaliloğlu [83% major cultivar], Kabaaşı [12% major cultivar], İsmailağa, 12-Kadıoğlu, 34-Hacihaliloğlu, No 8 Zerdali, Çataloğlu, Soğancı, Alkaya and 49-Alioğlu [minor cultivars 5%] samples from the national collection garden in Malatya Apricot Research Institute were examined in terms of some physical properties (moisture %, and water activity aw) and Texture profile analysis (TPA). These fresh samples were applied to sun (natural drying [GK] for 2-3 days) and oven (articifial drying [F] at 64°C for 12 hours) methods for drying. The changes of some physical properties (moisture and aw) in dried fruits were 17 [No 8 Zerdali] – 26 [Soğancı] %, 0.625 [No 8 Zerdali] – 0.739 [Soğancı] (GK) and 15.50 [Alkaya]–30.50% [Çataloğlu], 0.578 [Alkaya]– 0.746 [Çataloglu] (F), respectively. TA.XT plus texture analyzer was used to perform the texture profile analysis (TPA) (36 mm diameter cylindrical and 100 mm compression platen probes), puncture test (PT) (2 mm diameter punch probe) and knife test (extended craft knife) of the all dried (GK and F) apricot samples. The toughness results (kg) of knife test (GK and F) changed from 2.842 [Hacihaliloğlu]-7.602 [İsmailağa] to 3.535 [Hacihaliloğlu] 9.485 [İsmailağa], respectively, whereas the work of shear data (kg.mm) were 12.024 [Kadıoğlu]–38.702 [İsmailağa] and 11.008 [Çataloğlu] – 47.093 [İsmailağa], respectively. Texture profile analysis (TPA, hardness, springeness, cohesiveness, gumminess, chewiness and resilience) data among samples based on drying methods (GK and F) differed whereas the highest hardness İsmailağa (F) and the lowest chewiness 34-Hacihaliloğlu (F) and the highest resilence Soğancı (F). There was no fracturabilty and adhesivness data for all samples.

Keywords: *Turkish apricot cultivars, drying, TPA, physical properties*

THE VISCOELASTICITY OF HOMEMADE POMEGRANATE SOUR CONCENTRATES

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ABSTRACT

Pomegranate (*Punica granatum* L.) is a tropical, subtropical and one of the oldest known consumed fruit by people from the Southeast Asia to Uzbekistan, Iran, Turkey and the Mediterranean countries. According to the traditional method of producing pomegranate sour, after squeezing pomegranate to obtain its juice, this juice is being boiled to concentrate without adding any additives. The typical process steps are cleaning, crushing, extraction, filtration, clarification and evaporation, respectively. The consistency of pomegranate sour concentrates are generally very thick, even seem impossible to flow. The forces and the deformations needed in these processes to compute unit operations involving flow behavior are able to be measured by rheological properties. Accordingly, the viscoelastic properties of pomegranate sour concentrations must be known with the flow characteristics. In the literature, there is not much work done to investigate the rheological behavior of homemade pomegranate sour concentrates. Thus, the aim of this study was to determine the viscoelastic properties of homemade pomegranate sour concentrates. The viscoelastic properties of samples were measured by using a rheometer (Haake Rheostress 1, Germany) equipped with a plate-plate sensor (dia=35 mm, gap=1 mm) configuration at room temperature. The viscoelastic moduli, G' and G'' were measured at 1 *Hz* in duplicate. The data were obtained as a function of time by using a software (Haake RheoWin3 Data Manager, Germany). Among ten samples, only one sample exhibited overlapping G' and G'' values, whereas the other samples had higher G'' values than G', indicating viscous behavior. There was no crossover point for the G' and G''. This showed no change in rheological behavior of the samples during measurements. The complex viscosity values were in the range of 0.12-1.83 Pa.s. To understand rheology of pomegranate sour concentrates better, more rheological researches must be conducted.

Keywords: *pomegranate sour, viscoelasticity, rheology*

AUTHOR INDEX

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