

RHEOLOGICAL AND SENSORY PROPERTIES OF RED COLORED FRUIT SAUCES PREPARED WITH DIFFERENT HYDROCOLLOIDS

Şelale Kara Yalçınöz, Emine Erçelebi

Gaziantep University, Food Engineering Department, 27310, Gaziantep, Turkey

Abstract

Influence of type (locust bean gum (LBG), xanthan (XA), i-carrageenan (i-CARR)) and concentration (0.15%, 0.30%, 0.60%) of hydrocolloids upon rheological properties (consistency index (K), flow index (n), apparent viscosity (n_{app})) of strawberry, sour cherry and sweet cherry sauces were investigated. Correlation of rheological data and consumer acceptance were done by sensory analyses. Rheological results gave satisfactorily Power law fittings ($R^2 > 0.9107$). Sauces without hydrocolloid showed Newtonian behavior and, hydrocolloid addition caused a significant ($p < 0.05$) clear shift from Newtonian behavior to Non-Newtonians shear-thinning ($n < 1$) behavior except LBG. As compared to sauces prepared with neutral LBG, addition of hydrocolloid with negative charge (XA and i-CARR) showed better stability and good flow regimes, which may partially accounted by the electrostatic repulsion or higher viscosity. 0.30 % XA concentration was found to be a good alternative to prepare strawberry and sour cherry sauces with not disturbing sliminess and satisfactorily consumer acceptance.

Key words: red fruit, concentrate, hydrocolloid, sauce, rheology, sensory

1. INTRODUCTION

During the last years, the consumption of sauces has significantly increased due to new nutritional habits of consumers. For the food industry sauces are important since they represent products with a high added value, which are also quite easily manufactured (Mandala, Savvas & Kostaropoulos 2004). Among other uses, they serve as dressings for ice-cream, waffles and cakes, snacks, French fries, and fried or grilled meat. Usually they have a shape of concentrated slurries stabilized with surfactants. They contain also thickeners and spices to meet sensory demands. The use of stabilizers is optional and depends on the shelf life of a given product (Krystyjan et al. 2012).

Hydrocolloids are high molecular weight hydrophilic biopolymers, which serve various functions in food systems, such as enhancing viscosity, creating gel-structures, formation of a film, control of crystallization, inhibition of syneresis, improving texture, encapsulation of flavors and lengthening the physical stability, etc (Sahin & Ozdemir 2004; Kayacier & Dogan 2006). They directly affect overall acceptability of food product via increasing the physical stability and the overall mouth-feel properties (Marcotte, Hoshahili & Ramaswamy 2001). In this respect, Locust bean gum (LBG), it is also known as carob gum or carubin (Rocha et al. 2009), Xanthan gum (XA) and iota-carrageenan (i-CARR) were used during sauce preparation to increase viscosity and physical stability of the sauces. The properties of these hydrocolloids are summarized in Table 1. Hydrocolloid solutions are generally non-Newtonian pseudoplastic fluids and, power law model has been frequently used to characterize the flow behavior of hydrocolloid solutions (Kayacier & Dogan 2006).

Sensory analysis is widely used in elaboration of novel food products, their improvement and quality monitoring to satisfy consumer demands. The descriptors of the studied products and consumer opinions can be a kind of warning against the poor quality of the product (Krystyjan et al. 2012).

Numerous studies have been conducted on the rheological properties of sauces or the use of hydrocolloids as thickeners in sauces, dressings and mayonnaises; for instance, ketchup (Sahin & Ozdemir, 2004), red sorrel/roselle sauces (D'Heureux-Calix & Badrie 2004), dessert strawberry sauces (Sikora et al. 2007), sweet and sour sauces (Gibiński et al. 2006), commercial chili sauces (Gamonpilas et al. 2011), caramel sauces (Krystyjan et al. 2012), mayonnaise (Ma & Barbosa-Cánovas 1995), golden apple hot sauces (St. Louis & Badrie 2002), white model sauces (Mandala,

Savvas & Kostaropoulos 2004), sweet and salad sauces (caramel, honey, mustard, ketchup, mayonnaise) (Alvarez, Cancela & Maceiras 2004), commercial mustards (Juszczak et al. 2004) and Mexican sauces (Martinez-Padilla & Rivera-Vargas 2006). Sikora et al. (2008) reviewed the possibilities of application of different thickeners, and thickening systems, basic properties of thickening hydrocolloids, dyestuffs and flavorings applied in sauces, emulsifiers for sauces, dressings and mayonnaises, quality control of these products - microbiological, sensory, textural, rheological, the healthy aspects as well as future research work on sauces are discussed.

The aims of the present investigation, therefore, were to examine the effects of hydrocolloid type and concentration on the rheological and sensory properties of red colored fruit sauces prepared with LBG, XA and *i*-CARR at varying concentrations. This study was based on: (i) measurement of steady state rheological properties; (ii) evaluation of the adequacy of Power law models prepared by linear regression iterative procedure of the SigmaPlot; (iii) analysis of combined effect of sauce type, hydrocolloid type and hydrocolloid concentration on rheological properties (consistency index (*K*), flow index (*n*) and apparent viscosity (*n_{app}*)) of sauces by using a three-way ANOVA; (iv) determination of rheological optimum hydrocolloid type and concentration to prepare these sauces; and (v) verification of the rheological results by using the sensory analysis with 9 point hedonic scale for acceptability of the sensory qualities (appearance, taste, color, smell, consistency, sliminess (liquid and slippery like slime), and the overall acceptability of the sauces.

2. MATERIALS AND METHODS

2.1. Materials

Strawberry (*Fragaria x ananassa* Duch.), sour cherry (*Prunus cerasus* L.) and sweet cherry (*Prunus avium* L.) fruits were collected in Gaziantep, Southeast Anatolia, Turkey. All fruits were transported to the laboratory for analysis. Pectolytic enzyme, Panzym XXL, was kindly gifted by Sinerji A.Ş., Mersin, TURKEY. Locust bean gum (LBG) (G-0753), xanthan gum (XA) (G-1253) and *i*-carrageenan (*i*-CARR) (C-1138) were purchased from Sigma Chemical Company. Buffer salts, potassium dihydrogen orthophosphate and disodium hydrogen orthophosphate were purchased from Analar analytical reagent; BDH chemical Ltd. All the other reagents were of analytical grade.

2.2. Preparation of juices and concentrates

All the foreign materials such as pieces of branches and leaves and also unripe and damaged fruits were removed from fruit samples by hand. The cleaned fruits were washed under cold tap water, stalks and seeds were removed if it is available. Fruits were ground by using a laboratory blender. Juice was immediately filtered through muslin to remove pulp from the juice. Then the juice was depectinized with 1.0 % (w/v) Panzym XXL at 50 °C for 2 h. The depectinized juice was allowed to rest at 4°C for 24 h. The juice was again filtered through five layer muslin and finally double layer filter paper to obtain a clear juice. Clear juices were concentrated using BÜCHI Rotary Evaporator (Rotavapor R-3 model, BÜCHI Labortechnik AG, Flawil, Switzerland) at 40 °C up to 40-45 °Brix.

2.3. Preparation of sauces

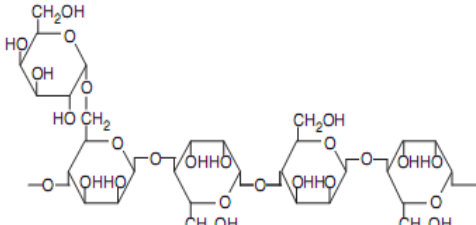
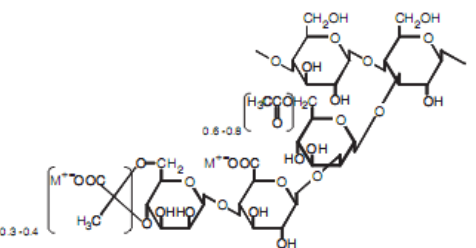
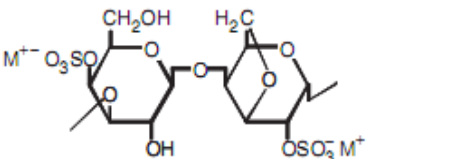
Phosphate buffer to dissolve hydrocolloids and, stock hydrocolloid solutions used in sauce preparation were prepared as follows:

Preparation of stock hydrocolloid solutions: LBG, XA and *i*-CARR stock solutions were prepared by dispersing the powders in phosphate buffer and vigorously stirring for 30 min at room temperature by magnetic stirrer, followed heating less than 50 °C for XA and *i*-CARR and, up to 80 °C for LBG until the solution became clear.

Sauces were prepared in the laboratory with previously prepared fruit juice concentrates. For each fruit juice concentrate, sauces prepared as without and with hydrocolloids of LBG, XA and *i*-CARR at

three different hydrocolloid concentrations (0.15, 0.30 and 0.60 % (w/v)) by using stock hydrocolloid solutions. In each case, to make 10 ml of sauce, appropriate quantity of stock hydrocolloid solution was dissolved in related fruit juice concentrate via vortex in the test tube.

Table 1. Properties of hydrocolloids

Type	Charge	Source	Chemical structure ^c	Solubility
LBG	Neutral ^a	Obtained from the seeds of the corob tree (<i>Ceratonia siliqua</i> L.) ^b	β -1,4-D-mannopyranose backbone with α -1,6-D-galactopyranose residues as single unit side chains Man/Gal ratio 3.2 – 3.5 	Completely soluble in hot water over 80°C ^d
XA	Anionic ^e	Aerobic fermentation of the microbe <i>Xanthomonas compestris</i> ^e	Linear β -1,4-D glucopyranose backbone with alternating O-3linked trisaccharide side chains of β -Dmannopyranosyl, β -1,4-D glucuronopyranosyl, α -1,2-D-mannopyranosyl with various amounts of acetyl and pyruvate substituents 	Either soluble in hot and cold water ^d
<i>I-CARR</i>	Anionic ^f	Extracted from red seaweed (<i>Rhodophyceae</i>) ^f	Linear chain of alternating β -1,3-D-galactopyranose-4-sulfate and α -1, 4-D-3,6-anhydrogalactose-2-sulfate units 	Soluble in hot water over 50°C ^g

^a(Rocha et al. 2009) ^b(Lazaridou, Biliaderis & Izydorczyk 2000) ^c(De Jong & Van De Velde 2007) ^d(Sahin & Ozdemir 2004) ^e(Rodríguez-Hernández & Tecante 1999) ^f(Černíková et al. 2008) ^g(Trius & Sebranek 1996)

2.4. Rheological measurements

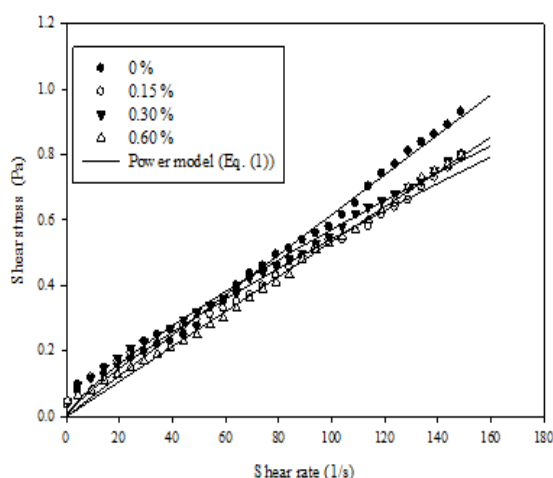
The rheological measurements were performed at 25±0.01 °C by using a CVOR Rheometer (Bohlin, Malvern, Worcestershire, United Kingdom) equipped with Peltier Temperature Controller Unit. The measuring system consisted of a cone and plate sensor with a diameter of 2 cm and cone angle of 2°. Shear rate range was 0–300 s⁻¹ within 600 s. For each measurement, 1 ml of sample was carefully poured over the plateau of rheometer. Each measurement was done in duplicate. Rheological parameters (shear stress, shear rate, apparent viscosity) were obtained from the Bohlin CVOR 150 data analysis software. Experimental flow curves were fitted to power law model (Krokida, Maroulis & Saravacos 2001):

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

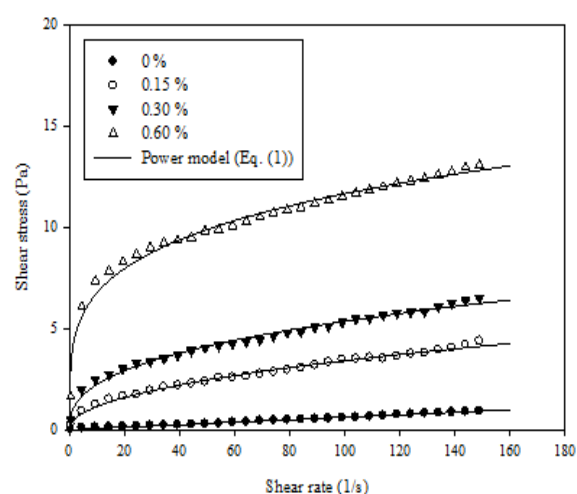
where σ is the shear stress (Pa), $\dot{\gamma}$ is the shear rate (s⁻¹), K is the consistency index (Pa sⁿ), and the exponent n , called the flow behavior index (dimensionless). The parameters (K , n) of the power law model (Eq. (1)) were estimated by linear regression iterative procedure of the SigmaPlot (SigmaPlot 10.0 Windows version, SPSS Inc.). Since for non-Newtonian fluids, apparent viscosity, η_{app} , is reported as a function of shear rate (Rha 1978), in this study, it was computed at shear rate of 50 s⁻¹ using power law parameters (K , n) due to the following equation:

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

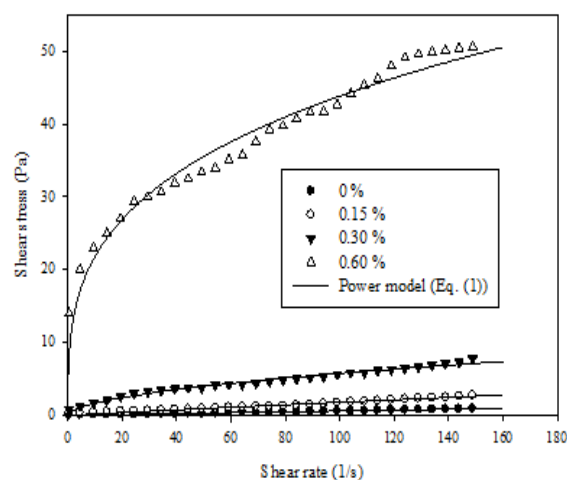
The shear rate of 50 s^{-1} was selected because of its being known as effective oral shear rate (Marcotte, Hoshahili & Ramaswamy 2001).



1 (a).



1 (b).



1 (c).

Fig. 1. Changes in shear stress with shear rate in (a) LBG added strawberry sauces; (b) XA added strawberry sauces; (c) *i*-CARR added strawberry sauces at different hydrocolloid concentrations.

2.5. Sensory analyses

The panel of 10 trained persons (seven females and three males) selected among the staff of Department of Food Engineering of the Gaziantep University of Turkey to participate in this research. Approximately 5 ml of sauce samples were served in plastic cups, coded with three digits chosen at random. The evaluation was called in three different sensations to obtain triplicate data. An evaluation form with a 9-point Hedonic scale (Elibol 1988) from 1=disliked extremely to 9=liked extremely (1-disliked extremely, 2-disliked very much, 3-disliked moderately, 4-disliked slightly, 5-neither liked nor disliked, 6-liked slightly, 7 liked moderately, 8-liked very much and 9-liked extremely) was used

by participants to assess the acceptability of the sensory qualities (appearance, taste, color, smell, consistency, sliminess (liquid and slippery like slime), and the overall acceptability of sauces. Participants were supervised during the test session and individual assessment was followed throughout the test, i.e., communication between panelists was not allowed. Panelists washed their mouths via drinking water during intervals of evaluations. Scores below 5 was taken as the unacceptable limit for rejection of samples for the responses of appearance, taste, color, smell, consistency, and overall acceptability, while, scores above 5 was taken as the unacceptable limit for rejection of samples in terms of sliminess. The averages of the triplicate data were modeled as radar chart by using Office excel 2007.

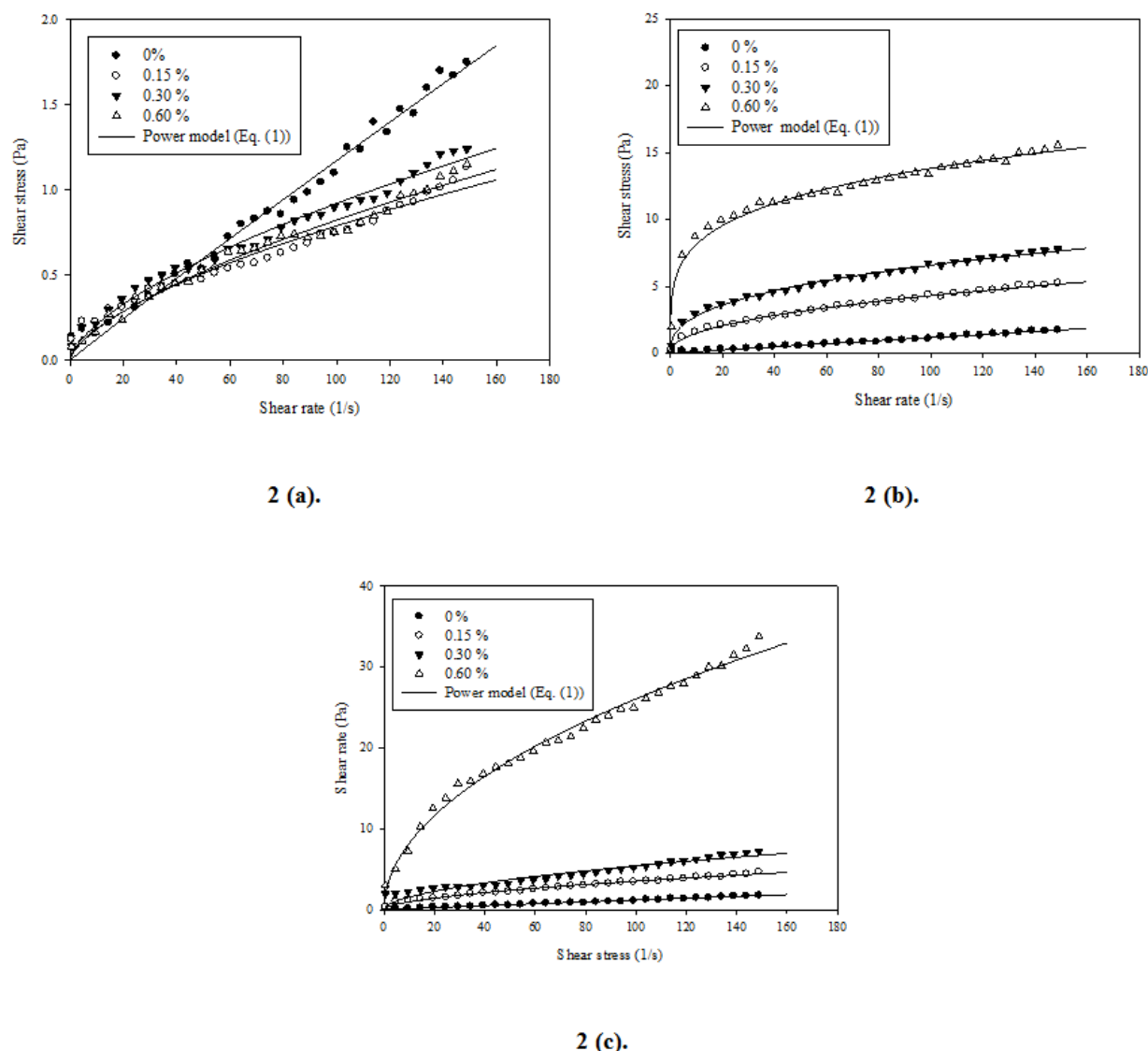


Fig. 2. Changes in shear stress with shear rate in (a) LBG added sour cherry sauces; (b) XA added sour cherry sauces; (c) *i*-CARR added sour cherry sauces at different hydrocolloid concentrations.

2.6. Statistical analysis

Experimental design was performed as a randomized planning with a factorial design with independent variables of sauce type (strawberry, sour cherry, and sweet cherry), hydrocolloid type (LBG, XA, *i*-CARR) and hydrocolloid concentration (0.15%, 0.30%, 0.60%). Combined effect of sauce type, hydrocolloid type and hydrocolloid concentration on rheological properties (consistency

index (K), flow index (n) and apparent viscosity (η_{app}) of sauces were examined. The results were given as means of two independent determinations. ANOVA was used to analyze all data based on a three-way mixed design and, the means were compared by Duncan's multiple range test at $p < 0.05$ significance level using SPSS version 17 (SPSS Inc., Chicago, IL, USA).

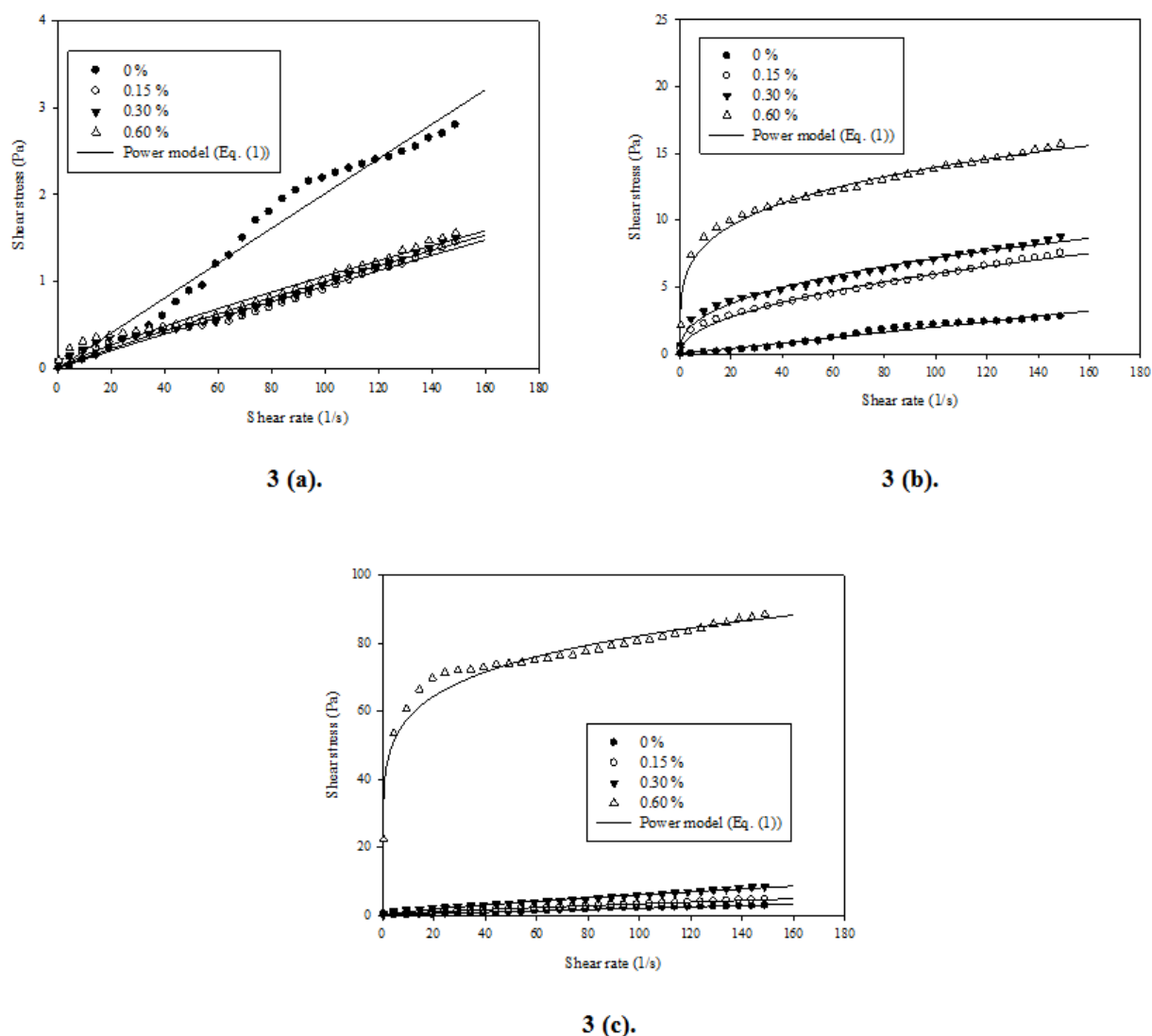


Fig. 3. Changes in shear stress with shear rate in (a) LBG added sweet cherry sauces; (b) XA added sweet cherry sauces; (c) *i*-CARR added sweet cherry sauces at different hydrocolloid concentrations.

3. RESULTS AND DISCUSSION

3.1. Rheological analyses

The parameters (n , K) obtained by fitting the power law model to the shear stress versus shear rate (Eq. (1)), and correlation coefficients, R^2 , and calculated η_{app} of sauces (Eq. (2)) at 50 s^{-1} by fitting power law model were presented in Table 2. The model appeared to be suitable for describing the flow behavior of sauces with high correlation coefficients (0.9107- 0.9943). Flow curves of sauces prepared without and with hydrocolloid at selected hydrocolloid concentrations of 0.15, 0.30 and 0.60 % (w/v) were shown in Figs. 1-3. The curves in these figures represent the Power law model fitted to the measured data.

The consistency index (K) of power law model ranged between 0.0054 and 40.8932 Pa $\cdot$ sⁿ (Table 2). ANOVA results from the data revealed that, K was significantly ($p < 0.05$) affected by both main factors (sauce type (S), hydrocolloid type (H) and hydrocolloid concentration (C)) and all two way ($S \cdot H$, $S \cdot C$, $H \cdot C$) and three way interaction of these factors ($S \cdot H \cdot C$) (Table 3). Hydrocolloid type and concentration had more significant ($p < 0.05$) effect on K than sauce type. As supposed $H \cdot C$ interaction was found to be the most predominant two way interaction. That is, in general, addition of different hydrocolloids with increasing hydrocolloid concentrations led to a significant ($p < 0.05$) increase in K except sauces prepared with LBG (Table 2). There was the significant ($p < 0.05$) differences test among K of sauces based on Duncan's multiple range tests.

It was seen from Table 2 that flow behavior indexes (n) were close to 1 (0.9572-0.9925), which clearly show that all sauces prepared without hydrocolloid shows Newtonian behavior, that is, at constant temperature and pressure, the viscosity of these sauces does not change with shear rate (Marcotte, Hoshahili & Ramaswamy 2001). Since our sauces were prepared from clarified and depectinized fruit concentrates, they exhibited Newtonian flow characteristics, which are supported by literature data, and even a small pseudoplasticity could be acceptable due to presence of some soluble solids, mostly pectins and tartarates (Giner et al. 1996; Juszczak & Fortuna 2003; Goula & Adamopoulos 2011). Table 3 shows that n was significantly ($p < 0.05$) affected by both the main factors and all interactions. Generally, hydrocolloid addition caused a significant ($p < 0.05$) clear shift from Newtonian behavior to Non-Newtonians shear-thinning behavior except LBG, as shown by a noticeable decrease in n values (Table 2). Multiple comparisons indicated that there were significant ($p < 0.05$) differences in the n of sauces due to hydrocolloid type and hydrocolloid concentration, while there was no statistically significant ($p > 0.05$) difference in the n of sauces prepared with strawberry and sweet cherry.

The apparent viscosity (η_{app}) of sauces computed by (Eq. (2)) at shear rate of 50 s⁻¹ using power law parameters (K , n) ranged between 0.0053 and 1.4794 Pa $\cdot$ s (Table 2). ANOVA results from the data revealed that, η_{app} was significantly ($p < 0.05$) affected by both main factors individually (S, H, C) and all binary interactions ($S \cdot H$, $S \cdot C$, $H \cdot C$) and three way interaction of these factors ($S \cdot H \cdot C$) (Table 3). Three way interactions of sauce type, hydrocolloid type and concentration had the most predominant contribution for change in η_{app} when compared to the others. In general, addition of different hydrocolloids with increasing hydrocolloid concentrations led to a significant ($p < 0.05$) increase in η_{app} except sauces prepared with LBG (Table 2). There were significant ($p < 0.05$) differences among the η_{app} of strawberry, sour cherry and sweet cherry sauces prepared with LBG, XA and *i*-CARR at varying hydrocolloid concentrations.

There was no definite trend in K , n and η_{app} values of the sauces prepared with LBG, which indicated that LBG did not show definite change in flow properties of related sauces (Table 2). Actually, LBG has many uses in food industry due to its ability to form very viscous solutions at a relatively low concentrations and their high stability upon pH or heat processing, mainly due to neutral character of this hydrocolloid (Camacho, Martinez-Navarrete & Chiralt 2005). In this study, LBG even caused the reduction in apparent viscosity η_{app} of sweet cherry sauces when compared to sauces prepared without hydrocolloid (Table 2). It can be concluded that LBG could not show its potential thickening ability in these sauces. Wei, Wang & Wu (2001) in their study related to flow properties of fruit fillings were reported that, some hydrocolloids may even decrease the η_{app} under certain circumstances. In addition, it was stated that when hydrocolloids are not properly hydrated, their potential for increasing viscosity does not fully appear.

All sauces prepared with XA and *i*-CARR showed non-Newtonian, shear thinning behavior ($n < 1$). Similar shear-thinning behavior also reported by Sikora et al. (2007) in dessert sauces thickened by starch-xanthan gum combinations. For all sauces prepared with these two hydrocolloids, the increase in hydrocolloid concentration was significantly ($p < 0.05$) accompanied with the increase in pseudoplasticity, shown by a decrease in n values, a measure of departure from Newtonian flow (Table 2). The smaller the n values the greater the departure from Newtonian behavior (Farhoosh & Riazzi 2007).

Table 2. Parameters from power law model ((Eq. 1)) fitting; consistency index, K , and flow behavior index, n , and apparent viscosity, η_{app} calculated (Eq. (2)) at 50 s⁻¹ of sauces

Sauce type	Hydrocolloid added	Hydrocolloid conc. (%) (w/v)	Consistency index (Pa.s ⁿ) $K \pm SE$	Flow index (Dimensionless) $n \pm SE$	R^2	(50/s) (Pa.s) $\eta_{app} \pm SE$
Strawberry	LBG	0	0.0064±0.0008	0.9915±0.0249	0.9918	0.0062±0.0004
		0.15	0.013±0.0015	0.8096±0.0225	0.9863	0.0062±0.0004
		0.30	0.0152±0.0013	0.7871±0.0180	0.9928	0.0066±0.0005
		0.60	0.0054±0.0005	0.9957±0.0209	0.9943	0.0053±0.0004
	XA	0.15	0.3857±0.0195	0.4734±0.0111	0.9917	0.0492±0.0035
		0.30	0.9390±0.0446	0.3784±0.0106	0.9877	0.0825±0.0058
		0.60	3.9189±0.1631	0.2369±0.0095	0.9731	0.1980±0.0140
	i-CARR	0.15	0.0247±0.0050	0.9323±0.0436	0.9692	0.0190±0.0013
		0.30	0.4928±0.0388	0.5344±0.0172	0.9844	0.0797±0.0056
		0.60	10.8725±0.6514	0.3027±0.0135	0.9648	0.7106±0.0502
Sour cherry	LBG	0	0.0135±0.0019	0.9693±0.0299	0.9875	0.0120±0.0008
		0.15	0.0438±0.0064	0.6277±0.0319	0.9614	0.0102±0.0007
		0.30	0.0399±0.0048	0.6571±0.0259	0.9785	0.0104±0.0007
		0.60	0.0487±0.0049	0.6383±0.0219	0.9830	0.0118±0.0008
	XA	0.15	0.5211±0.0216	0.4583±0.0092	0.9940	0.0626±0.0044
		0.30	1.1698±0.0437	0.3752±0.0083	0.9923	0.1015±0.0072
		0.60	4.7838±0.2071	0.2304±0.0099	0.9692	0.2356±0.0167
	i-CARR	0.15	0.2617±0.0210	0.5642±0.0175	0.9856	0.0476±0.0034
		0.30	0.4506±0.0818	0.5395±0.0398	0.9107	0.0744±0.0053
		0.60	2.6010±0.1479	0.5005±0.0125	0.9908	0.3685±0.0261
Sweet cherry	LBG	0	0.0208±0.0049	0.9925±0.0496	0.9724	0.0202±0.0014
		0.15	0.0119±0.0021	0.9507±0.0372	0.9795	0.0098±0.0007
		0.30	0.0149±0.0026	0.9133±0.0380	0.9764	0.0106±0.0007
		0.60	0.0212±0.0039	0.8502±0.0399	0.9690	0.0118±0.0008
	XA	0.15	0.6428±0.0342	0.4847±0.0117	0.9912	0.0856±0.0061
		0.30	1.1309±0.0589	0.4009±0.0116	0.9870	0.1085±0.0077
		0.60	4.7522±0.1863	0.2342±0.0089	0.9753	0.2376±0.0168
	i-CARR	0.15	0.0887±0.0078	0.7861±0.0190	0.9919	0.0384±0.0027
		0.30	0.1849±0.0200	0.7550±0.0233	0.9867	0.0709±0.0050
		0.60	40.8932±1.7382	0.1515±0.0099	0.9246	1.4794±0.1046

LBG: Locust bean gum.

XA: Xanthan gum.

i-CARR: i-carrageenan.

SE: Standard error.

R²: Correlation coefficients.

3.2. Effect of hydrocolloid type

Natural fruit juices are complex multicomponent systems, opalescent or turbid due to the presence of insoluble solids in suspension. These solids are mainly composed of carbohydrates and proteins, which are insoluble at the juice pH. The proteins have acid and basic groups whose degree of ionization depends on the pH and ionic strength of the liquid medium. Fruit juice particles have been suggested to be covered by a protective pectin layer, negatively charged at the juice pH. The pectin presents both in solution and coating of the particles prevents the contact between them, providing stability to the juice. To elaborate clarified juices the native pectin must be degraded and removed since it complicates the clarification process. After juice depectinization, only negatively charged colloidal particles smaller than 0.5 mm remain in suspension, since bigger particulate material precipitates by gravity (Benítez, Genovese & Lozano 2007). In terms of ionization, food hydrocolloids may or may not have electrical charge (Genovese & Lozano 2011). In literature, there are several studies covers the using hydrocolloids to improve the cloud stability of juices (Yamasaki, Yasui & Arima 1964; Koksoy & Kilic 2004; Liang et al. 2006; Erçelebi, Kara & İbanoğlu 2011; Genovese & Lozano 2011).

Table 3. Mean squares from analysis of variance of rheological properties of sauces

Source of variation	DF	Consistency index (Pa.s) <i>K</i>	Flow index (Dimensionless) <i>n</i>	(50/s) (Pa.s) <i>η_{app}</i>
<i>Main effects</i>				
Sample (S)	2	67.931*	0.52*	0.063*
Hydrocolloid (H)	2	134.400*	0.654*	0.334*
Concentration (C)	3	240.589*	0.891*	0.483*
<i>Two-way interaction</i>				
S*H	4	65.589*	0.25*	0.51*
S*C	6	68.815*	0.27*	0.53*
H*C	6	133.705*	0.133*	0.279*
<i>Three-way interaction</i>				
S*H*C	12	67.844*	0.22*	0.54*
Error		0.259	0.03	0.00*

*Significant at ($p < 0.05$).

LBG: Locust bean gum.

XA: Xanthan gum.

i-CARR: *i*-carrageenan.

Generally, the electrostatic repulsion is a good way of stabilization of particles in dispersed systems since juice particles are negatively charged after depectinization, addition of food hydrocolloids with negative charge is expected to increase electrostatic repulsive forces between particles (Genovese and Lozano 2011). In this study, XA and *i*-CARR are negatively charged ionic hydrocolloids, while LBG is a nonionic hydrocolloid with no charge (Table 1), which may probably accounts for better stability and flow regimes of sauces prepared with XA and *i*-CARR compared to LBG. This result confirmed to previous studies. Yamasaki, Yasui & Arima (1964) found that negatively charged colloids (like sodium alginate, carboxymethylcellulose, and arabic gum) in concentrations as low as 0.05%, completely inhibit apple juice clarification. Genovese & Lozano (2011) found that the greater stabilizing effect of carboxymethylcellulose in cloudy apple juice was basically due to its electronegativity. Zhang, Li & Cao (2004) also found that alginate-sodium with negative charge had an effective action in preventing sedimentation in combined vegetable juice. Liang et al. (2006) found

decrease of pulp sediment amount after addition of negatively charged ionic polysaccharides (xanthan, sodium carboxymethylcellulose, gellan) and the increase of pulp sediment amount after addition of a nonionic polysaccharide with no charge (guar) to reconstituted carrot juice.

Higher viscosity of the hydrocolloids is another constituent for the suspending stabilization of particles in dispersed system (Genovese & Lozano 2011). When compared to the sauces without hydrocolloid and sauces prepared with XA and *i*-CARR, hydrocolloid addition led to rise in K , thereby resulting in an increase in the η_{app} of sauces. The η_{app} of sauces showed an agreeing trend to K with respect to concentration levels (Table 2). Similar results were found by Sahin & Ozdemir (2004) in hydrocolloid addition to different formulated ketchups. As expected, K and η_{app} increased with increase in hydrocolloid concentration. It was resulted from decrease in fluidity possibly as a result of binding of water by hydrocolloid molecules leading to an increase in the resistance to flow (Sahin and Ozdemir 2004).

When we compared to sauces prepared with those negatively charged ionic hydrocolloids (XA and *i*-CARR), sauces prepared with XA showed better flow properties and stable sauces. XA has a three dimensional network consisting of the unique rigid, rod-like conformation while *i*-CARR has linear conformation (Table 1). This structural advantage of XA may result in better interaction with juice components, easy hydration and stable sauces with good flow properties.

From the flow curves of sauces prepared with XA and *i*-CARR (Figs. 1-3), it was clearly seen that XA showed a more steadily increase in pseudoplasticity than *i*-CARR. That is, *i*-CARR showed a slight transition in flow regimes as increasing hydrocolloid concentration from 0 to 0.15 and 0.30 %, respectively, but showed a sharp increase at 0.60 % hydrocolloid concentration. Gamonpilas et al. (2011) have been reported that the transition point between dilute and semi-dilute regimes of XA hydrocolloid is relatively low, making it very advantageous to achieve the desirable viscosity in food products, which supports our findings.

Trius & Sebranek (1996) reported that carrageenans are quite stable at pH levels of seven or higher, but below pH 7 chemical stability decreases, especially at high temperatures. At pH 5 to 7, changes are small, but as the pH is further lowered, hydrolysis of the carrageenan occurs with loss of viscosity and gelling ability. Once the gel is formed, however, hydrolysis is no longer a problem even at low pH levels, and the gel is stable. XA is being affected by pH values only more than 11 and less than 2.5 (Uan-on and Senge 2008). In this study, pH of strawberry concentrate, sour cherry concentrate and sweet cherry concentrates were 2.83, 2.95 and 3.75, respectively (Kara 2012). pH ranges of the concentrates (2.83-3.75) were suitable for XA activity, while *i*-CARR may possibly suffer from low pH. Also, *i*-carrageenan has gelling ability (Černíková et al. 2008), while XA is a non-gelling (Rodríguez-Hernández & Tecante 1999). Due to gelling ability of *i*-CARR, sauces prepared with higher *i*-CARR concentrations showed elastic but highly viscous jells, which was unacceptable.

Besides, it is reported that pseudoplastic characteristic of XA gives the advantage in terms of organoleptic quality, e.g., flavour release and mouth-feel, in food products and promotes mixability, pumpability and flowability characteristics, which are important factors for the design of flow systems (Gamonpilas et al. 2011). Consequently, XA can be regarded as a suitable stabilizer for all these fruit sauces. Moreover, for high viscosity and good mouth-feel characteristics, the hydrocolloid choice should be a hydrocolloid system having low n value, since high n value tends to feel slimy in the mouth (Farhoosh & Riazi 2007). In this respect, not only rheological characteristics but also sensory evaluation of sauces should be taken into consideration. Similar assumptions were done by Sahin & Ozdemir (2004).

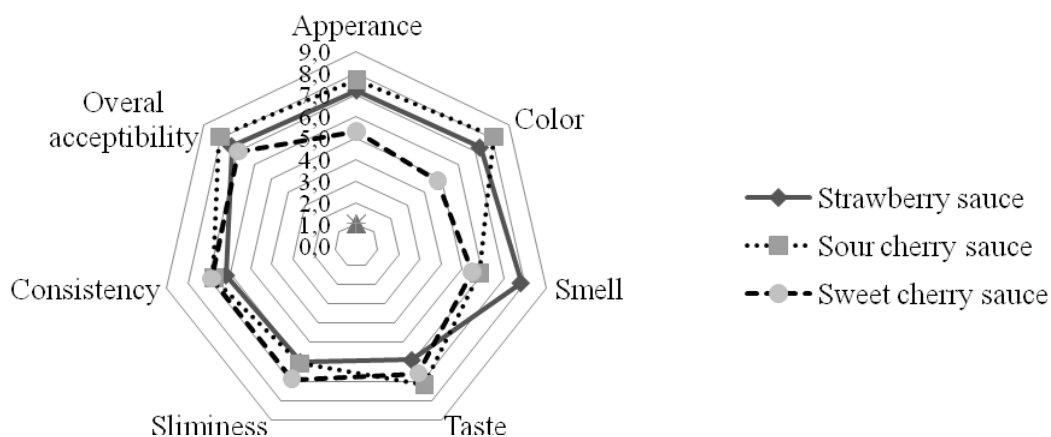


Fig. 4. Sensory characteristics of strawberry, sour cherry and sweet cherry sauces prepared with 0.30 % XA hydrocolloid concentration.

3.3. Sensory analysis of sauces

Correlation of rheological data and consumer acceptance were done by sensory analyses with the sauces which exhibited best flow properties, sauces prepared with XA hydrocolloid at 0.30 % hydrocolloid concentration, in terms of sensory qualities (appearance, taste, color, and smell, consistency and the overall acceptability) via 9-point Hedonic scale. To evaluate whether optimum hydrocolloid concentration was found or not, perceived sliminess in mouth which is directly related by hydrocolloid concentration was added as a critical parameter to the sensory analyses.

As shown in Fig. 4, all sensory properties of sauces were summarized in one graph. While the best fragrance was observed in strawberry sauce, the best overall acceptability, appearance, color and taste were observed in sour cherry sauce. When looked consistency and sliminess characteristics of sauces which are directly affected by hydrocolloid type and concentration, the highest values were observed in sweet cherry sauces, which could support that sweet cherry sauce was the rheological best stable sauce among them. However, when compared to other strawberry and sour cherry sauces, sweet cherry sauce had minimum sensory scores and consumer acceptance. When looked the physicochemical properties of sweet cherry concentrate used in sauce preparation, sweet cherry sauce's low color score and worse appearance could be result of its low total monomeric anthocyanin content (18mg/L) as compared to strawberry (3236 mg/L) and sour cherry (1767 mg/L) concentrates (Kara, 2012) and, its fast browning resulted from non-enzymatic browning during the juice production. So, it can be concluded that sweet cherry is not a good alternative to make this type of fruit sauce.

4. CONCLUSIONS

In this study, to observe the effect of hydrocolloid type and concentration upon rheological and sensory properties of red colored sauces were examined. Rheological observations gave good Power law fittings ($R^2 > 0.9107$). Sauces without hydrocolloid showed Newtonian behavior and, hydrocolloid addition caused a significant ($p < 0.05$) clear shift from Newtonian behavior to Non-Newtonians shear-thinning ($n < 1$) behavior except LBG. There was no definite trend in K , n and η_{app} values of the sauces prepared with LBG. For all sauces prepared with XA and *i*-CARR, an increase in hydrocolloid concentration was significantly ($p < 0.05$) accompanied with an increase in pseudoplasticity. As compared to sauces prepared with neutral LBG, addition of food hydrocolloids with negative charge

(XA and *i*-CARR) showed better stability and good flow regimes, which may partially accounted by the electrostatic repulsion or higher viscosity. Sauces prepared with XA showed a better thickening and increase in pseudoplasticity, and it was concluded as a better choice than *i*-CARR for sauce preparation. The verification of these rheological results was done by comparison of the sensory and physical properties of sauces prepared with XA at 0.30 % concentration. Sensory analysis proved that sauces prepared with 0.30 % XA concentration were found to be the best option to prepare strawberry and sour cherry sauces with not disturbing sliminess and satisfactorily consumer acceptance, while sweet cherry was found not suitable fruit for this type of sauce production with relatively low consumer acceptance. So, the fact of XA hydrocolloid is advantageous hydrocolloid in terms of sensory characteristics was proven as defined in literature (Benítez, Genovese & Lozano 2007; Gamonpilas et al. 2011).

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REFERENCES

- Alvarez E, Cancela MA & Maceiras R 2004, 'Comparison of rheological behavior of sweet and salad sauces', *International Journal of Food Properties*, vol. 7, no. 3, pp. 511–518.
- Benítez EI, Genovese DB & Lozano JE 2007, 'Effect of pH and ionic strength on apple juice turbidity: Application of the extended DLVO theory', *Food Hydrocolloids*, vol 21, no. 1, pp. 100–109.
- Camacho MM, Martinez-Navarrete N & Chiralt A 2005, 'Rheological characterization of experimental dairy creams formulated with locust bean gum (LBG) and λ -carrageenan combinations', *International Dairy Journal*, vol. 15, no. 3, pp. 243–248.
- Černíková M, Buňka F, Pavlínek V, Březina P, Hrabě J & Valášek P 2008, 'Effect of carrageenan type on viscoelastic properties of processed cheese', *Food Hydrocolloids*, vol. 22, no. 6, pp. 1054–1061.
- D'Heureux-Calix F & Badrie N 2004, 'Consumer acceptance and physicochemical quality of processed red sorrel/roselle (*Hibiscus sabdariffa* L.) sauces from enzymatic extracted calyces', *Food Service Technology*, vol. 4, no. 4, pp. 141–148.
- De Jong S & Van De Velde F 2007, 'Charge density of polysaccharide controls microstructure and large deformation properties of mixed gels' *Food Hydrocolloids*, vol. 21, no. 3, pp. 1172–1187.
- Elibol, S 1988, 'Inspection methods of organoleptic food', General Directorate of Protection and Control Professional Publications, Publication no: 3, Ankara, Turkey (in Turkish).
- Erçelebi EA, Kara Ş & İbanoğlu E 2011, 'Stability of Bitter Orange Juice-Olive Oil Salad Dressings Stabilized with Polysaccharides', *Journal of Food Science and Engineering*, vol. 1, pp. 297–302.
- Farhoosh R & Riazi A 2007, 'A compositional study on two current types of salep in Iran and their rheological properties as a function of concentration and temperature', *Food Hydrocolloids*, vol. 21, no. 4, pp. 660–666.
- Gamonpilas C, Pongjaruvat W, Fuongfuchat A, Methacanon P, Seetapan N & Thamjedsada N 2011, 'Physicochemical and rheological characteristics of commercial chili sauces as thickened by modified starch or modified starch/xanthan mixture', *Journal of Food Engineering*, vol. 105, no. 2, pp. 233–240.
- Genovese DB & Lozano JE 2001, 'The effect of hydrocolloids on the stability and viscosity of cloudy apple juices', *Food Hydrocolloids*, vol. 15, no.1, pp. 1–7.

- Gibiński M, Kowalski S, Sady M, Krawontka J, Tomasik P & Sikora M 2006, 'Thickening of sweet and sour sauces with various polysaccharide combinations', *Journal of Food Engineering*, vol. 75, no. 3, pp. 407–414.
- Giner J, Ibarz A, Garza S & Xhian-Quan S 1996, 'Rheology of clarified cherry juices', *Journal of Food Engineering*, vol. 30, no. 1-2, pp. 147-154.
- Goula AM & Adamopoulos KG 2011, 'Rheological Models of Kiwifruit Juice for Processing Applications', *Journal of Food Processing and Technology*. doi:10.4172/2157-7110.1000106.
- Juszczak L & Fortuna, T 2003, 'Viscosity of concentrated strawberry juice effect of temperature and soluble solids content' *Electronic Journal of Polish Agricultural Universities, Food Science and Technology*, Available at: <http://www.ejpau.media.pl>.
- Juszczak L, Witczak M, Fortuna T & Banys A, 2004, 'Rheological properties of commercial mustards', *Journal of Food Engineering*, vol. 63, no. 2, pp. 209–217.
- Kara Ş, 2012, 'Physicochemical and rheological properties of red colored fruit juice concentrates and their sauces', M.Sc. in Food Engineering, Gaziantep University, Turkey.
- Kayacier A & Dogan M 2006, 'Rheological properties of some gums-salep mixed solutions', *Journal of Food Engineering*, vol. 72, no 3, pp. 261–265.
- Koksoy A & Kilic M 2004, 'Use of hydrocolloids in textural stabilization of a yoghurt drink, ayran', *Food Hydrocolloids*, vol. 18, no. 4, pp. 593–600.
- Krokida MK, Maroulis ZB & Saravacos GD 2001, 'Rheological properties of fluid fruit and vegetable puree products: compilation of literature data', *International Journal of Food Properties*, vol. 4, no. 2, pp. 179–200.
- Krystyjan M, Sikora M, Adamczyk G & Tomasik P 2012, 'Caramel sauces thickened with combinations of potato starch and xanthan gum', *Journal of Food Engineering*, vol 112, no. 1-2, pp. 22–28.
- Lazaridou A, Biliaderis CG & Izydorczyk MS 2000, 'Structural characteristics and rheological properties of locust bean galactomannans: a comparison of samples from different carob tree populations', *Journal of the Science of Food Agriculture*, vol. 81, no. 1, pp. 68-75.
- Liang C, Hu X, Ni Y, Wu J, Chen F & Liao X 2006, 'Effect of hydrocolloids on pulp sediment, white sediment, turbidity and viscosity of reconstituted carrot juice', *Food Hydrocolloids*, vol. 20, no. 8, pp. 1190–1197.
- Ma L & Barbosa-Cánovas GV 1995, 'Rheological characterization of mayonnaise. Part I. Slippage at different oil and xanthan gum concentration', *Journal of Food Engineering*, vol. 25, no. 3, pp. 397–408.
- Mandala IG, Savvas TP & Kostaropoulos AE 2004, 'Xanthan and locust bean gum influence on the rheology and structure of a white model-sauce', *Journal of Food Engineering*, vol. 64, no. 3, pp. 335–342.
- Marcotte M, Hoshahili ART & Ramaswamy HS 2001, 'Rheological properties of selected hydrocolloids as a function of concentration and temperature', *Food Research International*, vol. 34, no. 8, pp. 695-703.
- Martinez-Padilla LP & Rivera-Vargas C 2006, 'Flow behaviour of Mexican sauces using a vane-in-a-large cup rheometer' *Journal of Food Engineering*, vol. 72, no. 2, pp. 189–196.
- Rha C 1978, 'Rheology of Fluid Foods', *Food Technology*, vol 32, pp. 77-82.
- Rocha C, Teixeira JA, Hilliou L, Sampaio P & Gonçalves MP 2009, 'Rheological and structural characterization of gels from whey protein hydrolysates/locust bean gum mixed systems', *Food Hydrocolloids*, vol. 23, no. 7, pp. 1734–1745.

- Rodriguez-Hernandes AI & Tecante A 1999, 'Dynamic viscoelastic behavior of gellan–i-carrageenan and gellan–xanthan gels', *Food Hydrocolloids*, vol. 13, no. 1, pp. 59–64.
- Sahin H & Ozdemir F 2004 'Effect of some hydrocolloids on the rheological properties of different formulated ketchups', *Food Hydrocolloids*, vol. 18, no. 6, pp. 1015-1022.
- Sikora M, Badrie N, Deisingh AK & Kowalski S 2008, 'Sauces and dressings: a review of properties and applications', *Critical Reviews in Food Science and Nutrition*, vol. 48, no. 1, pp. 50–77.
- Sikora M, Kowalski S, Tomasik P & Sady M 2007, 'Rheological and sensory properties of dessert sauces thickened by starch–xanthan gum combinations', *Journal of Food Engineering*, vol. 79, no. 4, pp. 1144–1151.
- St. Louis, C & Badrie N 2002, Effect of peel addition and storage on quality of golden apple (*Spondias cytherea* Sonn.) hot sauces, *Journal of Food Quality*, vol. 25, pp. 519–532.
- Trius A & Sebranek JG 1996, 'Carrageenans and their use in meat products', *Critical Reviews in Food Science and Nutrition*, vol. 36, no. 1, pp. 69-85.
- Uan-on T & Senge B 2008, Rheological behavior of pineapple puree mixed with different types of stabilizers (gum). Annual transactions of the nordic rheology society. Available at:http://www.nordicrheologysociety.org/Open_transactions/2008/Posters/UAN-ON.pdf
- Wei YP, Wang CS & Wu JSB 2001, 'Flow properties of fruit fillings', *Food Research International*, vol 34, no. 5, pp 377-381.
- Yamasaki M, Yasui T & Arima K 1964, 'Pectic enzyme in the clarification of apple juice', *Agronomical and Biological Chemistry*, vol. 28, no. 11, pp. 779–787.
- Zhang M, Li C & Cao P 2004, 'Effects of processing conditions of the green-leafy vegetable juice enriched with selenium on its quality stability', *Journal of Food Engineering*, vol. 62, no. 4, pp. 393–398.