Acta Alimentaria, Vol. 32 (4), pp. 383–393 (2003)

INFLUENCE OF HYDROCOLLOIDS AND SWEETENERS ON FLOW BEHAVIOUR OF PEACH NECTAR

N. NEDIĆ TIBAN[a*], V. PILIŽOTA[a], D. ŠUBARIĆ[a], D. MILIČEVIĆ[b] and M. KOPJAR[a]

[a] Faculty of Food Technology, University of Josip Juraj Strossmayer in Osijek, F. Kuhača 18, p.p. 709, HR-31107 Osijek. Croatia
[b] Faculty of Chemical Engineering, University of Tuzla, Univerzitetska 8, 75 000 Tuzla. Bosnia and Herzegovina

(Received: 17 March 2003; accepted: 12 July 2003)

Influence of adding six hydrocolloids, guar gum, carrageenan, carboxymethylcellulose and three types of pectin, and of sweeteners, aspartame and fructose, as replacement of sucrose, on flow behaviour of peach nectar was studied. A series of peach nectar samples (with approximately 65% fruit) was prepared using commercially processed peach purée with sucrose and substituting sugar with low-calorie sweetener aspartame and fructose (alone and in combination in a sweetness ratio of 1:1) taking into account their sweetness. To prevent reduction of viscosity and mouthfeel/body of low-calorie peach nectars, different concentrations of hydrocolloids were added. A control sample was prepared by mixing fruit purée with a sucrose solution (7% mass fraction) to provide a 14% (in total solids) nectar. Rheological measurements were carried out on a rotational viscosimeter Rheotest 3 at 20 °C and 5 °C. The flow of all peach nectars was characterized as pseudoplastic. Among all used hydrocolloids, addition of only 0.03% of carrageenan to the peach nectar was enough to obtain viscosity similar to the viscosity of the control sample.

Keywords: flow behaviour, hydrocolloids, peach nectar, viscosity

Production and consumption of low-calorie and dietetic products have been constantly increasing. From a consumer products standpoint, the beverage category has been distinguished in the past few years by innovative product development (HOLLINGSWORTH, 1997).

Fruit juice beverages and nectars, due to their chemical composition, can be considered for the development of sensory convincing formulations in the sector of light and dietetic products (MEYER & BURSIK, 1993). The major ingredient in almost any type of fruit juice and other beverages is water (from 85 to 95%). The remainder is mainly sugars, other sweeteners and minor constituents such as flavours, acidulants, preservatives, colourants, vitamins, minerals and texture-giving ingredients. While these minor constituents may make up less than 2–3% of the weight of any beverage, they may be the most important components because they define the character through flavour, acid-sugar and mouthfeel balance (GIESE, 1995). Replacement of sugar with intense sweeteners in fruit beverages reduces the calorie content, but removal of sugar

* To whom correspondence should be addressed.
Fax: +36-28-430-184; e-mail: szel@katki.hu

reduces mouthfeel/body as well. The mouthfeel is, to some extent, in correlation with the viscosity of the drink, which means that higher viscosity provides more mouthfeel/body (BUHL, 1994). Loss of consistency is usually compensated by addition of thickening agents, which also contributes to the physical stability of the low calorie product. Viscosity has also been reported to affect the perception of sweetness (BAYARRI et al., 2001). Most of the results were obtained with sucrose solutions, i.e. interactions between sucrose and hydrocolloids. In general, it was found that addition of thickeners in sucrose model solutions increased viscosity which led to reduction of the intensity of sweetness (IZUTSU et al., 1981; LAUNAY & PASQUET, 1982; PASTOR et al., 1996a). Further studies reported on actual products. PANGBORN and co-workers (1978) found that the effects of hydrocolloids (xanthan, hydroxypropylcellulose, sodium alginate and carboxymethylcellulose) on viscosity and sensory properties of three different beverages (tomato juice, orange juice and coffee) depended on the product. They indicated that the sweetness intensity of three beverages generally decreased in the presence of hydrocolloids. MÄLKKI and co-workers (1993) studied the influence of GG, oat gum and CMC on sensory perception of sweetness in sucrose, fructose and APM solutions. They found that the effect of the composition of the thickener on the perception of sweetness was greater than that of sensory viscosity. PASTOR and co-workers (1996a) studied the effects of interactions between each of three hydrocolloids (xanthan, guar gum and methylcellulose) and aspartame on sweetness and viscosity of low-calorie peach nectars.

Consequently, due to their functional properties to stabilize the insoluble particles, to thicken, and improve the consistency (viscosity), and mouthfeel of fruit nectars, hydrocolloids can be widely used (MARRS, 1996; BUFFO et al., 2001; GENOVESE & LOZANO, 2001). Their caloric value is quite low, making them useful particularly in the development of diet foods (KOKINI et al., 1984; MENDONÇA et al., 2001). Hydrocolloids are normally used by themselves or in combinations in low concentrations, ranging from 0.05%, or less, to about 5% (KRUMEL & SARKAR, 1975; DA SILVA & RAO, 1995; PSZCZOLA, 1995; CLARK, 1997; MARCOTTE et al., 2001).

The objectives of our study were to prepare low-calorie peach nectar formulations from commercially processed peach purée, using aspartame (APM) as a sweetener for sucrose replacement and hydrocolloids, guar gum (GG), carrageenan (CR), carboxymethylcellulose (CMC), pectin Classic AU 202, pectin Instant CJ 204 and pectin Combi AC 10, in different levels, in order to obtain products of similar viscosity to a 14% soluble solids of the regular commercial peach nectar, i.e. to a 14% soluble solids of the control peach nectar sample with sucrose. Fructose was also used as a sweetener, in combination with aspartame (in a sweetness ratio of 1:1), and alone, due to its sweetening power and functional properties which enhanced flavour, colour, and product stability (HANOVER & WHITE, 1993).

1. Materials and methods

1.1. Materials

The following ingredients were used: commercial frozen peach purée (total solids 10.2%, soluble solids 9.5%, and pH 3.88) provided by Frutex (Čelić, Bosnia and Herzegovina), commercial sugar (sucrose), fructose (Kemika, Croatia), aspartame (APM) (Nutrasweet, Switzerland), commercial citric acid (CA) (Kemika, Croatia) and hydrocolloids: guar gum (GG), carboxymethylcellulose (CMC) (Giulini Chemie, Ludwigshafen, Germany), carrageenan (CR) (Aquagel GU 805, Herbstreith & Fox KG, Neuenbürg, Austria), and three pectins identified by their trademarks, Classic AU 202 and Instant CJ 204 (68–76% degree of esterification), and Combi AC 10 (60–65% degree of esterification) (Herbstreith & Fox KG, Neuenbürg, Austria).

Rheological behaviour of a number of different hydrocolloids (model systems) has been investigated in earlier studies (ŠUBARIĆ, 1994; ŠUBARIĆ et al., 1994; PILIŽOTA et al., 1996; NEDIĆ, 2001). Based on the previous knowledge and experience from earlier studies, GG and CMC have shown interesting rheological properties which indicate possibilities for their use as thickeners and stabilizers of insoluble particles in various food, while CR and pectins already have a wide range of use as stabilizers as well as gelling agents (GORDON & KRISHNAKUMAR, 1990; DZIEZAK, 1991; BUHL, 1994; PSZCZOLA, 1995; SANDERSON, 1996; PASTOR et al., 1996b). APM in 0.035% concentration was used as a sweetener for peach nectar samples, due to its excellent taste profile (one of the leading low-calorie sweeteners) (INTERNATIONAL SWEETENERS ASSOCIATION, 2000). Concentration ranges for ingredients were selected on the basis of some previous results and data from the literature (PASTOR et al., 1996a, b).

1.2. Sample preparation

Solutions of hydrocolloids were previously prepared by dissolving certain mass fractions of hydrocolloids in distilled water by heating (to obtain maximum solubility) and by agitating by magnetic stirrer, taking into account the solubility of each hydrocolloid. Experimental peach nectar samples were prepared by mixing the fruit purée (approximately 65% fruit), after its thawing with solutions of chosen hydrocolloids, and with/or without APM, in distilled water. Hydrocolloid concentrations that gave similar viscosity ranges were previously selected. A control sample was prepared by mixing fruit purée with a sucrose solution (7% mass fraction), to provide a 14% (in total solids) nectar. One peach nectar formulation was prepared by adding fructose (4.1%), and another with APM and fructose in a sweetness ratio of 1:1, taking into account their sweetness intensity. pH was adjusted to 3.6 by addition of a 30% solution (w/v) of citric acid (CA). Table 1 and Table 3 describe formulations of the nectar samples used in this study.

1.3. Rheological measurements

Rheological measurements were performed by means of a rotational viscosimeter Rheotest 3 (VEB MLW, Germany) with concentric cylinder (fixture type N, R_i/R_e=0.98). For achieving the adequate and constant temperature Ultra Kryostat MK 70 (VEB MLW, Germany) was used. Shear stress against the increasing shear rates from the lowest value to 1312 s^{-1} (rising measurements) was measured. After this the highest shear rate, rotational rate was successively decreased to the lowest value (recurrent measurements) in order to define the type of flow at 20 °C and 5 °C. All the experiments were made in triplicate.

Rheological parameters, consistency coefficient (k) and flow behaviour index (*n*) were calculated according to the Ostwald de Waele's power-law model (BOURNE, 1982; KOKINI, 1987; GRIGELMO-MIGUEL et al., 1999):

$$\tau = k \cdot \gamma^{n}$$

where: τ: shear stress (Pa), k: consistency coefficient (Pas^n), γ: shear rate (s^{-1}), *n*: flow behaviour index (dimensionless).

Calculation of apparent viscosity μ (mPas) was done at 437 s^{-1} by applying the equation:

$$\mu = k \cdot \gamma^{n-1}$$

Analysis of variance was used to examine the influence of sources of variation (hydrocolloids, addition of sweeteners) on the rheological parameters of the peach nectar samples.

2. Results and discussion

The addition of different hydrocolloids and APM for mouthfeel improvement of the low-calorie fruit beverages has been studied by some authors (MEYER & BURSIK, 1993; PASTOR et al., 1996a, b). In this work, the possibility of preparing nectars with different sweeteners, as a replacement to sucrose, and combination of APM with six hydrocolloids was studied.

In the previous study (NEDIĆ, 2001) commercial peach nectar samples from the local market were analyzed for their main characteristics. Soluble solids content (ranged between 13.9 and 15.4%), pH values (between 3.52 and 3.81) and apparent viscosity at 437 s^{-1} and at 20 °C (between 9.51 and 11.39 mPas) were also studied. For presentation of measured values of apparent viscosity, shear rate at 437 s^{-1} was chosen, because this value is the nearest value to apparent viscosity of 500 s^{-1}, which is a good instrumental index of sensory viscosity for peach nectars (PASTOR et al., 1996b). Based on these results, a control sample was prepared with commercial peach purée (approximately 65% fruit) and sucrose (7% w/w) to get a 14.0% soluble solids nectar (apparent viscosity at 437 s^{-1} = 25.67 mPas). Commercial peach purée had 9.5% soluble solids and at 437 s^{-1} apparent viscosity of 21.38 mPas at 20 °C. Based on the abovementioned data, it is clear that commercial peach nectar samples had lower viscosities at the same temperature than the control sample and even than the commercial peach purée. For these reasons, one of the objectives of this paper was to obtain products of similar viscosity compared to a control sample (nectar with 7% w/w sucrose).

2.1. Influence of different sweeteners on rheological properties of peach nectars

Data obtained from the rheological measurements of nectars with different sweeteners are shown in Table 1. The rheological properties of peach nectars are adequately described according to Ostwald de Waele power-law model and power-law parameters (consistency coefficient k and flow behaviour index *n*). Control sample had the highest values of consistency coefficient at 20 (0.5656 Pas^n) and 5 °C (0.6613 Pas^n), i.e. the apparent viscosity was at 437 s^{-1} (25.67 and 34.50 mPas). Data (shear stress measured at 20 °C) were analysed using ANOVA (α=0.05, Table 2). Calculated F values (Fisher quotient values) expressed in Table 2 indicated that addition of APM had little influence on the rheological properties of peach nectars (α=0.05). Flow behaviour of peach nectars with fructose, and a blend of APM and fructose, in a sweetness ratio of 1:1 were also investigated. Nectar prepared with fructose (4.1%, w/w, based on the equisweetness value) had a slightly lower viscosity (apparent viscosity at 437 s^{-1} was 23.34 mPas) than nectar prepared with sucrose (apparent viscosity at 437 s^{-1} was 25.67 mPas). That was expected, since prepared nectar with fructose had a lower soluble solid content (10.9%). Both nectars had the highest F values (ANOVA), i.e. they significantly influence shear stress values at 20 °C.

2.2. Rheological parameters of peach nectars prepared with different hydrocolloids and APM

Since the effect of added hydrocolloids depends on the type and concentration of hydrocolloid, and on its flow behaviour, a series of hydrocolloids concentration that gave similar viscosity ranges was previously investigated (NEDIĆ, 2001).

The flow of all peach nectars, under this study, showed pseudoplastic behaviour, characterized by a flow behaviour index *n* value less than 1 at all concentrations and at both temperatures (20 °C and 5 °C). The flow behaviour index of nectars with added hydrocolloids practically did not change with the temperature (Tables 1 and 3). The range of *n* values for all nectars with hydrocolloids varied from 0.4571 to 0.5222 for hydrocolloids GG and CMC, while CR had the lowest values (from 0.3835 to 0.4156), which means more pseudoplastic behaviour. The increase in pseudoplasticity can be attributed to the interaction between peach purée and CR. Values of *n* varied from 0.4980 to 0.5427 for all types of nectar by adding different pectins.

Table 1. Peach nectar samples and their rheological parameters

Sample	Soluble solids (%)	t (°C)	k^a (Pas^n)	*n*	μ (mPas)	R^2
Peach nectar solution[b]	6.7	20	0.4869 ± 0.02	0.4891 ± 0.01	21.38	0.992
		5	0.5598 ± 0.03	0.5115 ± 0.01	27.64	0.996
Control sample[c]	14.0	20	0.5656 ± 0.02	0.4929 ± 0.002	**25.67**	0.994
		5	0.6613 ± 0.05	0.5167 ± 0.01	**34.50**	0.998
Nectar with fructose[d]	10.9	20	0.4834 ± 0.04	0.5053 ± 0.02	23.34	0.997
		5	0.6473 ± 0.02	0.5046 ± 0.01	31.05	0.996
Nectar with APM[e]	6.8	20	0.4726 ± 0.06	0.4917 ± 0.03	20.88	0.994
		5	0.5873 ± 0.03	0.5029 ± 0.01	28.10	0.996
Nectar with APM and fructose[f]	8.9	20	0.4983 ± 0.04	0.4909 ± 0.01	22.10	0.991
		5	0.6223 ± 0.08	0.5025 ± 0.01	29.80	0.994

Power-law parameters: k, consistency coefficient; *n*, flow behaviour index; μ, apparent viscosity at 437 s^{-1}; R^2, coefficient of determination

[a] Each value represents the mean (n=3) and standard deviation (SD);

[b] peach purée (67.82 g, 9.5% soluble solids), citric acid (0.15 g), water (to 100 g);

[c] peach nectar solution with sucrose (7% w/w);

[d] peach nectar solution with fructose (4.1% w/w);

[e] peach nectar solution with aspartame (0.035% w/w);

[f] peach nectar solution with aspartame (0.018% w/w) and fructose (2.1% w/w)

Table 2. Effect of different sweeteners on shear stress values (shear rate from 48.6 to 1312 s^{-1}) at 20 °C (ANOVA)

Source of variation	F	Fcrit
Peach nectar solution-nectar with sucrose	33.28	
Peach nectar solution-nectar with fructose	35.10	4.84
Peach nectar solution-nectar with aspartame	4.839	
Peach nectar solution-nectar with fructose and aspartame (1:1)	22.86	

$\alpha = 0.05$

Table 3. Rheological parameters of peach nectar samples with addition of different hydrocolloids and aspartame

Sample	t (°C)	k (Pas^n)	*n*	R^2
Nectar[a] with 0.075% GG[b]	20 5	0.7376 ± 0.10 0.9601 ± 0.06	0.4571 ± 0.02 0.4613 ± 0.01	0.997 0.996
Nectar with 0.075% GG and APM[c]	20 5	0.7169 ± 0.07 0.8891 ± 0.18	0.4705 ± 0.01 0.4789 ± 0.02	0.997 0.998
Nectar with 0.03% CR[d]	20 5	1.1441 ± 0.10 1.3313 ± 0.27	0.3904 ± 0.01 0.4046 ± 0.03	0.984 0.986
Nectar with 0.03% CR and APM	20 5	1.0982 ± 0.08 1.2122 ± 0.11	0.3835 ± 0.02 0.4156 ± 0.02	0.975 0.988
Nectar with 0.05% CMC[e]	20 5	0.4888 ± 0.06 0.7019 ± 0.05	0.5222 ± 0.02 0.5107 ± 0.01	0.999 0.999
Nectar with 0.05% CMC and APM	20 5	0.4476 ± 0.07 0.5985 ± 0.08	0.5210 ± 0.03 0.5221 ± 0.02	0.995 0.996
Nectar with 0.13% pectin AU 202	20 5	0.5864 ± 0.11 0.7359 ± 0.11	0.4980 ± 0.03 0.5075 ± 0.02	0.995 0.996
Nectar with 0.13% pectin AU 202 and APM	20 5	0.5008 ± 0.11 0.6501 ± 0.09	0.5146 ± 0.04 0.5191 ± 0.02	0.987 0.980
Nectar with 0.2% pectin CJ 204	20 5	0.4666 ± 0.01 0.6871 ± 0.05	0.5172 ± 0.01 0.5065 ± 0.01	0.994 0.993
Nectar with 0.2% pectin CJ 204 and APM	20 5	0.4555 ± 0.08 0.5527 ± 0.01	0.5269 ± 0.02 0.5427 ± 0.004	0.995 0.998
Nectar with 0.3% pectin AC 10	20 5	0.5134 ± 0.09 0.6007 ± 0.05	0.5046 ± 0.02 0.5237 ± 0.01	0.995 0.996
Nectar with 0.3% pectin AC 10 and APM	20 5	0.4752 ± 0.03 0.6714 ± 0.03	0.5170 ± 0.01 0.5101 ± 0.02	0.997 0.996

Power-law parameters: k, consistency coefficient; *n*, flow behaviour index; R^2, coefficient of determination
[a] peach nectar solution: peach purée (67.82 g, 9.52% soluble solids), citric acid; (0.15 g), water (to 100 g);
[b] guar gum;
[c] aspartame (0.035% w/w);
[d] carrageenan GU 805;
[e] carboxymethylcellulose

Table 4. Influence of addition of aspartame on consistency of peach nectar samples prepared with hydrocolloids (k values, ANOVA)

Source of variation	F	Fcrit
Between used hydrocolloids	86.57	2.82
Between samples with and without addition of aspartame	12.57	4.84

$\alpha = 0.05$

In order to demonstrate the influence of addition of APM on consistency (consistency coefficient values) of peach nectar samples prepared with different hydrocolloids, analysis of variance was executed. Fisher quotient values (F) obtained for two parameters (type of hydrocolloid and samples with or without addition of APM) were significantly higher than the limiting values (Table 4, α=0.05), which means that the influence of hydrocolloid used and APM on the rheological properties is statistically significant. PASTOR and co-workers (1996a) investigated the effect of APM concentration on sensory viscosity of peach nectar products. They found that for some hydrocolloids (GG, xanthan) increasing of APM concentration did not influence sensory viscosity of products, and for other (methylcellulose), there was a significant effect on perceived product viscosity. In the other study, PASTOR and co-workers (1996b) optimized the acceptability of a low-calorie peach nectar formulation using different levels of GG (0.082 to 0.922 g l^{-1}) and APM (0 to 4.0 g l^{-1}) based on Response Surface Methodology in order to obtain a product of similar acceptability to a 14 °Brix regular peach nectar. The optimized formulation (0.6 g l^{-1} APM and 0.6 g l^{-1} GG) was not different in acceptability from a control sample with sucrose or from some commercial samples.

When comparing the viscosity levels perceived in nectar samples with hydrocolloids and apparent viscosity of control sample, it can be said that the peach nectar solution with CR needed the lowest concentration of hydrocolloid (0.03%) (Fig. 1). Calculated F values expressed in Table 5 showed that the addition of 0.03% CR in the peach nectar sample had the highest influence on rheological properties (shear stress values at 20 °C, α=0.05). This is in agreement with the results from Table 3, which shows that the values of consistency coefficient of nectar with 0.03% CR are the highest in comparison with other values of consistency coefficient (1.1441 Pas^n at 20 °C and 1.3313 Pas^n at 5 °C). Calculated k values were also very high in a peach nectar with GG which correlated with the ANOVA results (α=0.05) (Table 5). Pectins had the lowest values of consistency compared with other examined hydrocolloids. Nectar formulation with 0.13% of pectin AU 202 in the peach nectar sample had the highest influence on rheological properties among the pectins (shear stress values at 20 °C, α=0.05). The addition of 0.3% of pectin Combi AC 10 to the peach nectar produced viscosity similar to the control sample, which was the highest quantity of all hydrocolloids used.

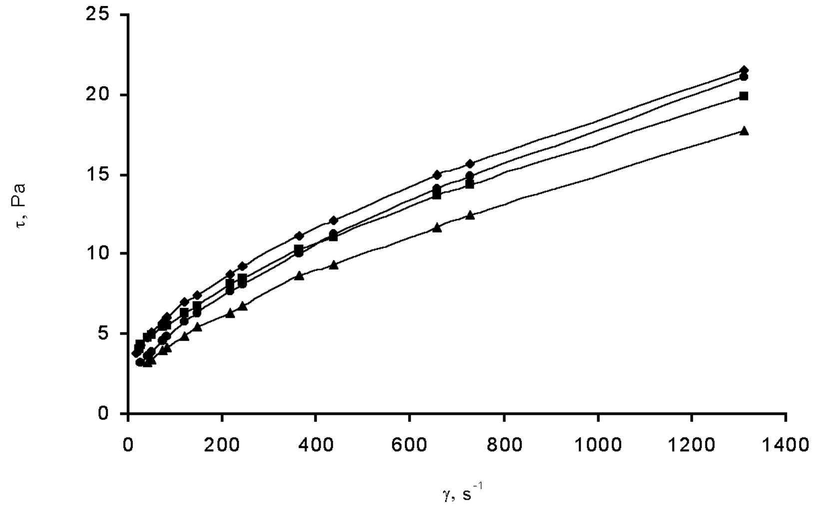

Fig. 1. Shear stress (τ) vs shear rate (γ) for prepared peach nectars at 20 °C. Peach nectars were prepared from peach purée (67.82 g), citric acid (0.15 g), (with/without CR and aspartame) and distilled water (to 100 g); control sample was prepared by adding sucrose (7% w/w). ♦: Nectar with 0.03% CR; •: control sample; ■: nectar with 0.03% CR and 0.035% APM; ▲: peach nectar solution

Table 5. Effect of different hydrocolloids on shear stress values of peach nectars (shear rate from 40.5 to 1312 s^{-1}) at 20 °C (ANOVA)

Source of variation	F	Fcrit
Peach nectar solution–nectar with 0.075% GG	84.18	
Peach nectar solution–nectar with 0.03% CR	161.65	
Peach nectar solution–nectar with 0.05% CMC	29.66	4.75
Peach nectar solution–nectar with 0.13% pectin AU 202	31.95	
Peach nectar solution–nectar with 0.2% pectin CJ 204	19.69	
Peach nectar solution–nectar with 0.3% pectin AC 10	28.07	

$\alpha = 0.05$

3. Conclusions

The power-law equation is an adequate model for describing the flow behaviour of the peach nectar samples prepared with hydrocolloids and aspartame. All investigated peach nectars showed pseudoplastic behaviour at 20 °C and 5 °C. The addition of different sweeteners to peach purée solutions significantly alter the rheological parameters, except in the case of APM. Nevertheless, the results of variance analysis showed that all examined hydrocolloids as well as addition of APM in combination with hydrocolloids had significant influence on the consistency of peach nectar formulations. CR GU 805 (α=0.05) had the biggest influence on consistency of peach nectar, among all hydrocolloids. Addition of 0.03% of CR to the peach nectar produced viscosity similar to viscosity of the control sample.

*

This work was financially supported by the Croatian Ministry of Science and Technology. We are grateful to Mr M. HAJDAREVIĆ at "Frutex", Čelić, Bosnia and Herzegovina for providing the peach purée, and Herbstreith & Fox KG, Neuenbürg, Austria for providing the hydrocolloids.

References

BAYARRI, S., RIVAS, I., COSTELL, E. & DURÁN, L. (2001): Diffusion of sucrose and aspartame in kappa-carrageenan and gellan gum gels. *Fd Hydrocolloids*, *15*, 67–73.

BOURNE, M.C. (1982): *Food texture and viscosity: Concept and measurement*. Academic Press Inc., San Diego, p. 200.

BUFFO, R.A., REINECCIUS, G.A. & OEHLERT, G.W. (2001): Factors affecting the emulsifying and rheological properties of gum acacia in beverage emulsions. *Fd Hydrocolloids*, *15*, 53–66.

BUHL, S. (1994): Application of pectins in soft drinks and beverages. *Fruit Processing*, *1*, 8–9.

CLARK, R. (1997): Evaluating syrups using extensional viscosity. *Fd Technol.*, *51*(1), 49–52.

DA SILVA, J.A.L. & RAO, M.A. (1995): Rheology of structure development in high-methoxyl pectin/sugar systems. *Fd Technol.*, *49* (10), 70–73.

DZIEZAK, J.D. (1991): A focus on gums. *Fd Technol.*, *45* (3), 116–130.

GENOVESE, D.B. & LOZANO, J.E. (2001): The effect of hydrocolloids on the stability and viscosity of cloudy apple juices. *Fd Hydrocolloids*, *15*, 1–7.

GIESE, J. (1995): Developments in beverage additives. *Fd Technol.*, *49* (9), 64–72.

GORDON, I.R. & KRISHNAKUMAR, V. (1990): Hydrocolloids in West Europe. *Ifi Nr.*, *3*, 30–33.

GRIGELMO-MIGUEL, N., IBARZ-RIBAS, A. & MARTÍN-BELLOSO, O. (1999): Rheology of peach dietary fibre suspensions. *J. Fd Engng*, *39*, 91–99.

HANOVER, L. & WHITE, J. (1993): Manufacturing, composition, and applications of fructose. *Am. J. clin. Nutr*. 5 (suppl), 724s–732s; cit. from: *J. Am. Diet. Assoc., 98*, 580–587 (1998).

HOLLINGSWORTH, P. (1997): Beverages: redefining new age. *Fd Technol.*, *51* (8), 44–51.

INTERNATIONAL SWEETENERS ASSOCIATION (2000): Aspartame: its components and safety. *Fruit Processing*, *6*, 213–216.

IZUTSU, T., TANEYA, S., KIKUCHI, E. & SONE, T. (1981): Effect of viscosity on perceived sweetness intensity of sweetened sodium carboxymethylcellulose solutions. *J. Texture Stud.*, *12*, 259–273.

KOKINI, J.L. (1987): The physical basis of liquid food texture and texture-taste interactions. *J. Fd Engng*, *6*, 51–81.

KOKINI, J.L., BISTANY, K.L. & MILLS, P.L. (1984): Predicting steady shear and dynamic viscoelastic properties of guar and carrageenan using the Bird-Carreau constitutive model. *J. Fd Sci., 49,* 1569–1572.

KRUMEL, K.L. & SARKAR, N. (1975): Flow properties of gums useful to the food industry. *Fd Technol.*, *29* (1), 36–44.

LAUNAY, B. & PASQUET, E. (1982): Sucrose solutions with and without guar gum: rheological properties and relative sweetness intensity. *Prog. Fd Nutr. Sci.*, *6*, 247–258.

MÄLKKI, Y., HEINIÖ, R.L. & AUTIO, K. (1993): Influence of oat gum, guar gum and carboxymethyl cellulose on the perception of sweetness and flavour. *Fd Hydrocolloids*, *6*, 525–532.

MARCOTTE, M., HOSHAHILI, A.R.T. & RAMASWAMY, H.S. (2001): Rheological properties of selected hydrocolloids as a function of concentration and temperature. *Fd Res. int.*, *34*, 695–703.

MARRS, W.M. (1996): Rheology as an indicator of functionality. *The World of Ingredients*, *1–2*, 38–40.

MENDONÇA, C.R., ZAMBIAZI, R. & GRANADA, G.G. (2001): Partial substitution of sugars by the low-calorie sweetener sucralose in peach compote. *J. Fd Sci*., *66*, 1195–1200.

MEYER, H. & BURSIK, H. (1993): Fruit juice beverages and nectars with Nutrasweet®. *Fruit Processing*, *7*, 252–254.

NEDIĆ, N. (2001): *Utjecaj hidrokoloida i sladila na reološka i senzorska svojstva kašastog soka breskve.* (Influence of hydrocolloids and sweeteners on rheological and sensory properties of peach nectar.) M. Sc. Thesis, Faculty of Food Technology and Biotechnology, University of Zagreb.

PANGBORN, R.M., GIBBS, Z.M. & TASSAN, C. (1978): Effect of hydrocolloids on apparent viscosity and sensory properties of selected beverages. *J. Texture Stud.*, *9*, 415–436.

PASTOR, M.V., COSTELL, E. & DURÁN, L. (1996a): Effects of hydrocolloids and aspartame on sensory viscosity and sweetness of low calorie peach nectars. *J. Texture Stud.*, *27*, 61–79.

PASTOR, M.V., COSTELL, E., IZQUIERDO, L. & DURÁN, L. (1996b): Optimizing acceptability of a high fruit-low sugar peach nectar using aspartame and guar gum. *J. Fd Sci.*, *61*, 852–855.

PILIŽOTA, V., ŠUBARIĆ, D. & LOVRIĆ, T. (1996): Rheological properties of CMC dispersions at low temperatures. *Fd Technol. Biotechnol.*, *34* (2–3), 87–90.

PSZCZOLA, D.E. (1995): Drinks for everyone! *Fd Technol.*, *49* (9), 30.

SANDERSON, G.R. (1996): Gums and their use in food systems. *Fd Technol.*, *50* (3), 81–84.

ŠUBARIĆ, D. (1994): *Proučavanje promjena reoloških svojstava smjesa hidrokoloida i škrobova pri niskim temperaturama.* (The study of changes of the rheological properties in mixtures of hydrocolloids and starches at low temperatures.) M. Sc. Thesis, Faculty of Food Technology and Biotechnology, University of Zagreb.

ŠUBARIĆ, D., PILIŽOTA, V. & LOVRIĆ, T. (1994): Rheological properties of some hydrocolloid mixtures at low temperatures. *Fd Technol. Biotechnol., 32* (2–3), 71–76.