Technical paper

Formulation and Development of a New Prebiotic Cereal-based Dairy Dessert: Rheological, Sensory and Physical Attributes

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This study aimed to develop a new prebiotic dairy dessert by adding different concentration of cereal flours (10 – 16% w/w), inulin (6 and 8% w/w) and sugar (2 and 4% w/w) into dairy dessert formulation. A mixture design approach was used to create nine formulation of dessert samples. Desserts were evaluated by consumers who were asked to answer a check-all-that-apply (CATA) question. Water holding capacity (WHC) and syneresis values were also measured. Based on our results different concentration of flour, inulin and sugar resulted in different sensory and rheological properties. Dessert samples with higher content of inulin and sugar had lesser consistency coefficient and storage modulus. Samples with higher level of flour and lower level of inulin and sugar had good physical stability and presented appropriate sensory characteristics. Results showed that data from both consumers' response to CATA question and rheological measurements presented the same information.

Keywords: cereals, dessert, inulin, rheology, sensory analysis

Introduction

Today in food industry, modern technologies permit us to change food products in ways that provide added health benefits to consumers. These products, namely “functional foods” are those that promise consumers improvement in targeted physiological functions (Roberfroid, 1999). With this in mind, functional foods were launched in Japan in the early 90's as an alternative to hinder chronic disease and to reduce health-care costs (Shimizu, 2003). It

is very important, in development of functional food products to select appropriate foods to function it. In this regard dairy desserts could be good options because milk desserts are extensively consumed products worldwide and dessert market is growing at a great rate with numerous new products and concepts (Morais *et al.*, 2014). Combining cereals and milk provides opportunity to increase the nutritional value of cereal-based products (Helland *et al.*, 2004). Cereal grains possess beneficial constituent such as

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vitamins, several minerals (especially micronutrients such as iron and zinc), dietary fiber and phytochemicals with antioxidant properties (Singh *et al.*, 2013). Multigrain blends of cereals can offer food products with number of advantages associated with these grains. Mixing different grains enable to maximize their nutritional, functional and sensory properties (Mandge *et al.*, 2014). For production of *fereni*, a well-known traditional cereal-based dessert in Iran, about 4 – 6% rice flour and 10 – 12% sugar is added to cold milk; upon heating a thickened and palatable dessert is achieved.

Recently, food industries have been investigating more eagerly the application of dietary fibers such as those from inulin, oligofructose, lactulose, and others so as to develop products such as biscuits, cereal bars, dairy infant formulas, yogurts, and frozen desserts with vigorous health claims. Dietary fibers possess many useful physiological effects on health (Reddy *et al.*, 1997).

Sensory and physical properties of the commercial products are influenced with type and content of their ingredients. Owing to complex interaction among the different components of a dairy dessert, adding ingredients in addition to basic formulation could cause changes in the technological behavior of the products (Tárrega *et al.*, 2005). The main textural attributes of desserts such as thickness, creaminess and smoothness are very important with respect to consumer response (Elmore *et al.*, 1999; De Wijk *et al.*, 2006). Besides, in another study, the texture of milk desserts was characterized using attributes such as creamy, thick, airy, smooth and fatty (Weenen *et al.*, 2005). Wischmann (2002) investigated the effect of starch concentration on both viscoelasticity and flow behavior of dairy cream model systems and detected that they all revealed time-dependent and pseudoplastic flow; creams viscoelastic nature ascribed to a gelled structure. Remarkable differences in the rheological behavior have been observed in commercial samples (Batista *et al.*, 2002; Tárrega *et al.*, 2004; Tárrega *et al.*, 2005). Recent studies revealed that inulin has very important effect on both rheological and sensory properties of dairy products. In low fat dairy desserts, the addition of inulin provides a creamier mouth feel and imparts a better-balanced round flavor (Torres *et al.*, 2010; Tárrega and Costell, 2006). Adding 6% inulin to low fat custard increased viscosity and improved sensory properties (Tárrega and Costell, 2006).

Obtaining and accurate analyzing of consumers' perception is a key step in development of food products. To withstand in the market competition, a food product has to be developed considering consumer wants and needs. One of the newest techniques for collecting information about consumers' perception of sensory characteristics of food products is the application of check-all-that-apply (CATA) question (Adams *et al.*, 2007; Ares *et al.*, 2010; Dooley *et al.*, 2010). These questions made up of a list of words or phrases from which respondents should specify those they consider that apply to answer a definite question. The most important benefit of this type of question is that it allows multiple

choices to be chosen, rather than restricting respondents to choose only one answer or enforcing consumers to focus their attention and assess specific attributes (Smyth *et al.*, 2006).

Correlations are commonly applied to evaluate the relationship between the instrumental values and sensory evaluation in order to predict consumer responses or to assess quality control tools or parameters (Szczesniak, 1987). Some authors studied the correlation between rheological techniques and sensory texture of milk desserts that have been evaluated by trained assessors (De Wijk *et al.*, 2003; Janssen *et al.*, 2007). Ares (2011) by using multi factor analysis (MFA) showed that data from rheological measurements and consumer responses to check-all-that-apply (CATA) question given similar information. However, even though many studies have reported rheological properties and sensory attributes of dairy desserts, little information has been reported concerning the rheological properties and consumers' texture perception in functional desserts.

This study has been undertaken to develop a palatable cereal-based dairy dessert with low sugar and fat in addition to having prebiotic and better understanding about the relationship between rheological parameters and sensory texture of this product.

Material and Methods

Ingredients and desserts preparation Sugar powder, milk powder, whole wheat flour, corn flour, saffron and rosewater were obtained from the local market. Carrageenan (Type HMF) was supplied by Robertet (Can, France). Stabilized whole oat flour (inactivated fat hydrolyzing enzymes) was donated by Seed and Plant Improvement Institute (Karaj, Iran). Pure stevia powder (stevioside 80%) which is 100 – 150 times sweeter than table cane sugar was purchased from Herbo Veda India. Inulin (Frutafit® TEX!) was obtained from SENSUS (Netherlands) (Average chain length ≥ 22 monomers). For preparation of the nine dessert samples the extent of milk powder (10%), carrageenan (0.02%), saffron (0.02%), stevia (0.02%), and rosewater (3%) were kept constant. Desserts were formulated by different concentration of mixed cereal flours (50% oat flour, 25% wheat flour, 25% corn flour), inulin and sugar, according to mixture design (Table 1). The remains of formulation consisted of water. Ranges of variables in mixture design were chosen based on our previous studies to get acceptable sensory characteristics. A Thermomix Food Processor (Thermomix TN 31, Wuppertal, Germany) was used to produce different formulated desserts in Doosheh Dairy Research and Development Laboratory (Amol, Iran). In order to reduce the raw flavor of cereal flours based on our tradition in production of *fereni*, it was soaked in a small part of recombined milk 24 h before the preparation of the desserts. The other solid ingredients (except for saffron) were mixed with this suspension, and then remained water was added and the mixture was stirred for 20 min at 90°C in Thermomix in setting 5. Then, saffron and rosewater were added and the process was carried out for further 3 min under mild

Table 1. Concentration of cereal flours, inulin and sugar of dessert samples.

Sample	Mixed Cereal Flours (%)	Inulin (%)	Sugar (%)
1	10	6	2
2	10	8	2
3	14	8	4
4	16	8	2
5	10	6	4
6	16	6	4
7	10	8	4
8	16	6	2
9	13	7	3

agitation. The samples were put into plastic containers, closed to keep away from drying and stored refrigerated (4 – 6°C) for 24 h, prior to their evaluation.

Rheological Experiments Rheological experiments were performed with a physica MCR 301 rheometer (Anton-Paar, GmbH, Graz, Austria). Temperature was controlled using a Peltier system equipped with a fluid circulator. For the dessert samples, a serrated plate-and-plate system (40 mm in diameter, 1 mm gap) was used. Before measurements were performed, samples were left standing for five minutes to allow structure recovery and temperature equilibration. Obtained data were analyzed using Rheoplas software (version 3.21) (Anton-Paar). Flow curves determined in the shear rates of 0.01 – 500 s⁻¹. Shear rate was increased logarithmically in 200s. The power law and Herschel-Bulkley models were applied to characterize the rheological properties of the samples:

$$\eta_a = m\dot{\gamma}^{n-1} \quad \text{.....Eq. 1}$$

$$\tau = m\dot{\gamma}^n + \tau_0 \quad \text{.....Eq. 2}$$

In the power law model (Eq. 1) and Herschel-Bulkley model (Eq. 2), flow behavior index (n) and consistency coefficient (m) values are obtained by fitting the shear rate versus apparent viscosity values (Steffe, 1996). Where is shear stress (Pa), is yield stress (Pa), is apparent viscosity (Pa·s), *m* is consistency coefficient (Pa·sⁿ), $\dot{\gamma}$ is shear rate (s⁻¹) and *n* is flow behavior index (dimensionless). For determining of viscoelastic properties of the desserts, strain sweep tests were first performed (0.01 – 1000%, 1 Hz) to specify the limiting value of linear viscoelastic range (Matta *et al.* 2006). Frequency sweep tests were done using a frequency ramp from 0.01 to 15 Hz at a constant strain within the linear viscoelastic range for each sample and at a constant temperature 10°C. The important rheological parameters obtained are the storage modulus, *G'*, that reflects the energy stored during a cycle, and loss modulus, *G''*, that reflects the viscous energy dissipation during that cycle. Frequency dependence of *G'* and *G''* was described by the power law model:

$$G', G'' = a \omega^b \quad \text{.....Eq. 3}$$

In the power law model (Eq. 3), *a* is a constant and *b* may be referred to as the frequency exponent. Values of *b* that show the extent of frequency dependence demonstrate expedient information regarding the viscoelastic characteristics of food materials.

Assessing syneresis and water holding capacity For evaluation of syneresis, 20 g of freshly prepared dessert poured into glass bottles of 120 mm height and 15 mm diameter, covered and stored under refrigeration (5 ± 1°C) for 72 h. The desserts were evaluated for stability versus gravity by calculating mass loss percentage and the analyses were carried out in triplicate (White *et al.*, 2008).

The water holding capacity (WHC) of the desserts was measured in triplicate according to Granto *et al.*, (Granato *et al.*, 2012). 20 g of dessert (DE) was poured into cylindrical glass measurement cell and centrifuged for 30 minutes at 5000 rpm. After centrifugation the whey expelled (WE) was separated, weighed and expressed as percent. The WHC was defined as: WHC = 100[(DE-WE)/DE]. WHC was measured after 72 h storage under refrigeration.

Consumer sensory evaluation Forty consumers aged between 19 to 48 years old (62% female and 38% male consisting of students and staff) were recruited to participate in dessert test at the sensory service center of the National Nutrition & Food Technology Research Institute (Shahid Beheshti University of Medical Science, Tehran, Iran). Consumers were chosen based on their availability and willingness to participate in sensory evaluation and were regular dairy desserts consumer on a daily basis. Participants were asked to try the dessert and score their overall liking using a 9-point hedonic scale. Thereafter, they were asked to check all attributes that applied to presented desserts. Results of new researches about sensory profile of milk desserts were considered for selection of terms used in the CATA questionnaire (Bruzzone *et al.*, 2012; Ares *et al.*, 2012). Twenty gram of each of the nine samples was presented to consumers using a balanced complete block design. Samples served at 10°C in odorless plastic containers codified with three- digit random numbers. The test was carried out in a sensory laboratory designed in accordance with ISO 8589 (ISO 2007). Participants cleansed their palates with mineral water prior to each sample evaluation. Regarding to ethical issues, consumers were told that they were going to try dairy dessert containing cereal flours. Participants gave informed consent and were given a gift for their participation.

Statistical analysis *Instrumental analysis:* The effects of cereal flours, inulin and sugar concentration on the flow parameters (*m* and *n*) values, the viscoelastic parameters (*G'*, *G''* and *tan δ*) values at 1 Hz, syneresis and WHC were analyzed by analysis of variance (ANOVA). For comparison of parameters Tukey's comparison test was used (*p* ≤ 0.05). The experiments were performed in triplicate. In order to investigate the simultaneous influence of flour, inulin and sugar on the rheological properties of

Fig. 1. Flow behavior of dessert samples.

Table 2. Average values of flow behavior index (n), consistency index (m), apparent viscosity at 50 S^{-1} and yield stress (τ_0).

Sample	n	$m \text{ (Pa} \cdot \text{s}^n)$	$\eta_{50} \text{ (Pa} \cdot \text{s)}$	$\tau_0 \text{ (Pa)}$	R^2
1	0.44 ^c	34.87 ^c	2.71 ^c	0 ^c	0.99
2	0.65 ^b	7.19 ^d	1.31 ^d	0 ^c	0.99
3	0.43 ^c	36.52 ^c	2.65 ^c	0 ^c	0.99
4	0.39 ^c	59.34 ^{ab}	5.94 ^b	13.28 ^b	0.99
5	0.71 ^{ab}	4.28 ^d	1.06 ^d	0 ^c	0.98
6	0.40 ^c	51.54 ^b	4.87 ^b	11.65 ^b	0.99
7	0.79 ^a	2.01 ^d	0.78 ^d	0 ^c	0.99
8	0.31 ^d	64.08 ^a	8.13 ^a	19.42 ^a	0.98
9	0.43 ^c	38.93 ^c	2.80 ^c	0 ^c	0.98

Note: Values are the mean of three replications; different letters in each column indicate significant differences ($p < 0.05$).

formulated desserts, polynomial models were fitted to two responses: apparent viscosity and $\tan \delta$. Besides, counter plots were created.

Sensory analysis: Frequency of use each of the CATA question was determined by counting the number of consumers that used that descriptor to describe each sample. Cochran's Q tests were run on the assessor $\times$ products table, independently for each attributes, to determine significant differences between samples for each of the term included on the CATA question. In order to get a bi-dimensional representation of the samples corresponding analysis (CA) was used on a matrix where the rows were the desserts (9 lines) and the columns were the attributes used by the consumers to describe the samples. The consumer overall liking score was considered as supplementary variable.

Correlation between rheological and sensory results: Multiple factor analysis (MFA) was conducted to study the correlation between consumers' responses to CATA question and rheological data. This technique determines the positioning of the samples in a

single map. All statistical analysis was performed by software XLSTAT for window version 2016 (Adinsoft, Paris, France).

Results and Discussion

Rheological properties Figure 1 illustrates the flow curve for treatments with different concentration of inulin, mixed flour and sugar. Viscosity variation with shear rate showed that all samples presented non-Newtonian shear-thinning flow. This could be ascribed to collapse of the network structure caused by stress. As anticipated, apparent viscosity values increased with the increment of flour concentration. Yield stress was observed for treatments 4, 6 and 8 and their flow data fitted well to the Herschell-Bulkley model with R^2 values between 0.98 and 0.99. The yield stress values of desserts were in the range of 11.65 to 19.42 Pa. These data are compiled in Table 2. Previous study revealed that with the increment of starch (main component of flour) concentration, volume fraction of solids in starch dispersion would raise and this resulted in rise in yield stress. This phenomenon could be ascribed

Table 3. Polynomial models fitted, lack of fit (LF), significance level (P) and coefficient of determination (R^2) for apparent viscosity (Pa.s) and loss tangent of the desserts according to the component proportions of the flour (x_1), inulin (x_2) and sugar (x_3).

Attributes	model	LF	P	R^2
Apparent viscosity (η_{s0})	$Y_1 = 41.3x_1 + 17.3x_2 + 53x_3 - 91.4x_1x_2 - 184x_1x_3$	0.03	0.002	0.98
Loss tangent ($\tan \delta$)	$Y_2 = 12.4x_1 + 38x_2 + 65.7x_3 - 90x_1x_2 - 116.9x_1x_3$	0.02	0.003	0.95

to the entanglements brought about by the existence of the highly branched, high molecular weight of amylopectin (Rao and Tattiyakul, 1999).

Data from the flow curve of remained samples fitted well to the Ostwald-Dewaele model. The consistency index (m) was in the range of 2.01 to 64.08 and range of flow behavior index (n) was 0.312 to 0.795. The mean n values were proportionate to those for commercial desserts. The extent of flow behavior index ($0 < n < 1$) affirmed that desserts had typical characteristic of shear thinning behavior. This behavior was in accordance with that detected in starch-milk model system and dairy desserts in market (Abu-Jdayil *et al.*, 2004; Tárrega and Costell, 2006; González-Tomás *et al.*, 2008). As might be expected, increase in flour (starch) content had a significant effect on rheological value; the consistency index values augmented with starch concentration, whilst the flow index values decreased. It is interesting to note that desserts with higher content of inulin had lesser m values and higher n values. For example m value for sample1 is greater than sample 2. The models, adjusted to apparent viscosity and loss tangent of desserts, are showed in table 3. R^2 for apparent viscosity (0.95) and loss tangent (0.98), signifies the extent of variation in concentration of flour, inulin and sugar that affect these responses. Lack of fit was significant. According to Waszczynskyj *et al.* (1981) in analysis of variance, once the pure error mean square assumes very low values compared to the total error, the significant lack of fit should not be taken into account, as in the case of η_{s0} and $\tan$ in the present study. Fig. 2a shows influence of flour, inulin and sugar concentration on apparent viscosity of dessert sample. As can be observed, with the increase in inulin and sugar concentration, apparent viscosity reduced. Antagonist interaction both between flour and inulin and between flour and sugar had the most important effect on apparent viscosity. This fact could be attributed to higher affinity of inulin over starch for water. Upon the formation of the starch gel, it immobilizes the large amount of water.

Inulin is extremely hygroscopic with higher affinity for the water over starch; therefore it could decrease water accessibility for other ingredients of food systems. Inulin molecules encompass a lot of water due to formation of junction zones. When inulin is added, bound water in inulin is more mobile in comparison with starches, due to molecules of inulin are shorter and more mobile. Viscosity and gel strength would be less due to water presently bound to smaller and more rapid moving inulin chains (Bishay, 1998). Tarrega and Costell (2006) studied the effect of adding 6% long-chain inulin ($DP \geq 23$) on sensory and rheological properties

Fig. 2. Counter plot for desserts apparent viscosity (a) and loss tangent (b).

of fat-free milk based desserts, containing various concentrations of starch (2.5%, 3.25% and 4%). The authors reported that the capability of inulin as fat substitute was excellent only in samples with 2.5% and 3.25% starch. In desserts with lower starch concentration (2.5% and 3.25%), there was enough water in the system, so that inulin did not influence the starch granule swelling process. For samples with the higher starch concentration (4%), with part of water bound to the inulin chains, swelling of the starch granules was limited, the volume fraction of swollen particles was lower and the system viscosity decreased. With regard to starch content of cereal grains, dessert samples in present study contain at least 5% starch (Serna-Saldivar, 2010)

In puddings, starch is applied to give viscosity and a smooth texture. Starch gelatinization brings thickness to the solution.

Fig. 3. Frequency sweep of moduli G' and G'' for dessert samples.

During production of pudding, starch granules swell and are fragmented and solubilized to different level in accordance with the intensity of heating and mechanical shear. Texture, appearance and stability of starch-based desserts are influenced by the distribution of starch between swollen granules, fragmented granules and solubilized polymers. At the same time, presence of other ingredients determines starch granules behavior in food systems. Hydrophilic solutes such as sucrose compete for water, and can slow down and prevent starch swelling. Sugars affect gelatinization onset temperature in connection with their impact on water activity and water volume fraction. Sugar reduces the rate of thickening and enthalpy of gelatinization (Thomas and Atwell, 1999). Therefore, in development of functional dairy desserts, it is important to know to what extent changes in formulation of the product, affect its rheological features and acceptability. By addition of inulin, product structure in particular was influenced, hence, both rheological properties and perceived texture were changed. Several investigations have revealed that the prosperous application of inulin as a fat replacer in low-fat dairy desserts depends on the balance of inulin value with the other ingredients present in the formulation (Tárrega and Costell, 2006; Gonzales-Thomas *et al.*, 2009). In this context, attention must be paid to test different combination of ingredients in formulation in order to attain appropriate combination, so that unfavorable changes which mischaracterize the products are avoided.

The mechanical spectra of the dessert samples 7 and 8 obtained from the frequency sweep tests are illustrated in Figure 3. Results for the rest treatments were encompassed within the range determined by samples 7 and 8. The value of the storage modulus (G') and loss modulus (G'') as a function of angular frequency are depicted in the frequency range 0.16 to 16 Hz (1 to 100 rad/s). Frequency curves illustrated that for samples 1, 3, 4, 6, 8 and 9 the G' and G'' moduli slightly increased with frequency and G' values were higher than G'' values over the whole frequency rate,

indicating the weak gel-like structure of the samples. Such trend in G' and G'' values is recognized to be typical for weak gel-like structure (Nunes *et al.*, 2006) and is observed when the packing of the swollen starch granules is high enough to occupy a large part of the volume. Structure of starch based desserts is mainly affected by the increase in volumetric fraction of the dispersed phase, constituted by swollen starch granules (Abu-Jdayil, 2004). In remained samples the viscous response predominated over the elastic one. For comparison of viscoelastic characteristics, G' , G'' and $\tan \delta$ values at a frequency of 1 Hz were considered (Table 4). The $\tan \delta$ is an effective indicator for characterizing the viscoelasticity of dairy desserts. The increase of $\tan \delta$ values indicates a change from an elastic nature toward a more viscous nature. As can be seen from Fig. 2b, with increased amount of flour and with decreased amount of inulin and sugar, $\tan \delta$ was increased. Antagonist interaction both between flour and inulin and between flour and sugar had the most important effect on $\tan \delta$. The parameters of power law model which demonstrates the frequency dependence of G' modulus of the samples are shown in Table 4, where, the coefficient a represents the magnitude of G' , and the exponent b displays the slope of the relationship between modulus and frequency. As stated in the Table 4, the coefficients of determination (R^2) were 0.97 to 0.99, suggesting fitness of power law model to characterize viscoelastic properties of dessert samples. Samples 1, 3, 4, 6, 8 and 9 had higher a values than those of samples 2, 5 and 7, indicating that their G' values change slightly with frequency, and means that former had a stronger elastic structure than the latter. In a study about the effect of different concentration of sugar on viscoelastic properties of starch paste (5%), it was found that G' values of starch pastes were significantly reduced with increase in sugar values. The magnitude of a (in power law model) also reduced with increase in sugar concentration. According to their report, decrease of G' values appeared to be a result of the inhibition of (starch) molecular chain

Table 4. Average values of storage modulus (G'), loss modulus (G''), loss tangent angle ($\tan \delta$) at 1 HZ and Power-law parameters for the elastic modulus ($G' = a \omega^b$) of the dessert samples.

Sample	G' (Pa)	G'' (Pa)	$\tan \delta$	a (Pa.s ^b)	b	R^2
1	320.8 ^c	194.31 ^c	0.60 ^c	301.27 ^c	0.172 ^c	0.99
2	15.1 ^e	22.4 ^d	1.48 ^b	201.96 ^d	0.336 ^b	0.99
3	252 ^d	151.8 ^c	0.60 ^c	289.3 ^c	0.178 ^c	0.99
4	607 ^b	257 ^b	0.42 ^d	430.12 ^{ab}	0.140 ^d	0.97
5	4.14 ^e	6.73 ^d	1.62 ^b	110.46 ^e	0.355 ^b	0.99
6	544 ^b	261.04 ^b	0.48 ^d	408.57 ^b	0.157 ^d	0.98
7	3.12 ^e	8.55 ^d	2.74 ^a	101.13 ^e	0.640 ^a	0.99
8	1410 ^a	351 ^a	0.25 ^e	466.9 ^a	0.128 ^d	0.99
9	240 ^d	141.36 ^c	0.59 ^c	297.45 ^c	0.169 ^c	0.98

Note: Values are the mean of three replications; different letters in each column indicate significant differences ($p < 0.05$).

Fig. 4. Principal component analysis performed on the correlation matrix of the mean values of rheological parameters (□) and representation of the samples (●).

rearrangement that tend to form a more ordered structure or a crystalline structure (Chang *et al.*, 2003). According to Juszczak and coworkers (2012) who studied rheological properties of dough containing inulin, inulin increase $\tan \delta$ and viscous property of dough. They reported that values of a (in power law model) reduced with rising levels of used inulin. They suggest that addition of inulin augments viscous character of samples. From a rheological point of view, starch suspensions have viscoelastic properties and both the matrix of dissolved macromolecules and existence of starch swollen granules would affect their behavior. Therefore factors affecting quality of starch granules could change viscoelastic properties of food systems (Luallen, 1985).

Figure 4 depicts the representation of the nine evaluated desserts in the first two dimensions of the PCA. First and second PC components accounted for 88.73% and 9.57% of the variance of the data set, respectively. This Figure shows a perceptual map

based on rheological data analysis of desserts. Examination of the pattern of sample distribution in Figure 3 indicated that samples 4, 6 and 8 that were located in right side of PC1 had higher η_{50} , G' and G'' values, while they revealed less intensity in n and $\tan \delta$ values. Samples 2, 5 and 7 were suited at the left side of PC1, indicating that these desserts had less η_{50} , G' and G'' values and higher n and $\tan \delta$ values than other desserts.

Evaluation of syneresis and water holding capacity Figure 5 shows levels of syneresis and water holding capacity (WHC) in desserts. Treatments showed statistical differences in these two attributes. The level of syneresis ranged from 1.07 to 9.52% and WHC ranged from 60.88 to 98%. The syneresis index, after 72 h of storage, was high for samples 2, 5 and 7 followed by samples 1, 3 and 9, whereas samples 4, 6 and 8 exhibited the smallest amount of exuded water. Overall, syneresis and WHC data obviously revealed that desserts with higher level of inulin and sugar had greater

Fig. 5. Level of syneresis (left) and water holding capacity (WHC) (right) in different treatments after 72 h of refrigerated storage. Different letters indicate significant differences ($P < 0.05$).

syneresis and lower WHC. As mentioned before this impact could be explained by the different water affinities among starch, inulin and sugar. As reported by Bishay (1998), inulin has more affinity for the water than the starch polysaccharides. The water that is bound to the inulin chain is more mobile than when it is bound to the starch; this is simply as a result of inulin having shorter, more mobile molecules. Kohyama and Nishinari (1991) proposed that sugars stabilize the crystalline areas of starch and immobilize water molecules. This probably increases gelatinization temperature. Sugar also competes for water with gluten and other flour components.

Changing of starch due to gelatinization is favorable in plenty of food products. Starch gels are, however, thermodynamically unstable and encounter changes, consequently impact on their technological suitability (Lapasin, 2012). During cold storage, starch molecules reassociate in a complex recrystallization process known as retrogradation, which is often associated with water released from the gel (syneresis) (Hoover and Manuel, 1995). These changes may eventuate textural and visual gel deterioration. Knowledge of WHC of gels is important in practical application. It was found that gels may suffer from loss of water, when exterior pressure is exerted or temperature is fluctuated. The loss of water may result in shrinking of the gels, changing texture and decreasing quality. Hence, WHC is a substantial measure in assessing the acceptability of food gels (Thomas and Atwell, 1999).

Sensory evaluation The most frequently used descriptor for CATA were creamy, sweet, bright color, nice flavor, no floury flavor, smooth and thick, suggesting that CATA question was capable to find out differences in consumer percentage of the sensory properties of evaluated desserts (data not shown). A significant differences was detected among the frequency of above mentioned attributes using Cochran's Q tests ($p < 0.05$), suggesting that this methodology was capable of determining the different sensory stimuli provoked by the desserts. The same results were reported by Bruzzone *et al.* (2012).

For creating a sensory map of the samples, CA was carried out on CATA question. The First dimension explains 71.91% of the variance in the data set and second dimension explains an additional 11.91% of the variance. As showed in Figure 6 the first

dimension associated with the terms not creamy and fluid and correlated negatively with the terms creamy and thick. According to cluster analysis samples categorize into four groups. One group located at positive value of the first dimension that comprise samples 2, 5, 7 and was explained with terms of not creamy, fluid, bright, sweet and not floury flavor. Samples 4, 6 and 8 were placed at negative value of first dimension and were specified by the terms thick, creamy, heterogeneous and aftertaste. Finally, samples 1, 3 and 9 were situated apart from the rest and were mainly characterized by the terms sweet, homogeneous, and nice flavor. In addition to evaluation of each attribute, consumers were asked to evaluate overall liking of the nine desserts. It was obviously found that terms firm, creamy and thick were positively correlated to overall liking. In return, the attributes fluid and not creamy were negatively correlated to overall liking, indicating that consumers might dislike desserts with these properties (Figure 7). These findings were in accordance with that detected by other authors in dairy dessert samples. Prior researches revealed that creaminess and thickness are very substantial to consumers, so-called "drivers of liking" (Bruzzone *et al.*, 2012). The Trend of liking showed that samples 4, 6 and 8 received excellent appreciation by the consumers (Figure 7). It is interesting to note that, despite the fact that the samples had very low quantity of fat, consumers perceived the most of samples creamy and very creamy, especially samples 4, 6 and 8. This can be ascribed to presence of inulin. Addition of long-chain inulin to low-fat starch based dairy desserts modifies the perceived texture in different ways. Characteristic of long-chain inulin to act as fat substitute is based on its ability to create microcrystal, which interact with each other, thereby forming small aggregates which occlude a great amount of water, forming a fine and creamy texture that provides a mouth sensation similar to that of fat (Tárrega and Costell, 2006). However, as discussed previously, care should be taken when using inulin, since in desserts with high starch content, inulin could act as diluent, thereby limiting swelling of the starch granules. Overall, results demonstrated that although samples 4, 6 and 8 characterized by "aftertaste" and "floury flavor" (Fig. 6), they received high score in a sensory point of view. This could be explained by the fact that consumers presumably liked attributes such as thickness and

Fig. 6. Representation of the samples (●) and the terms (□) in the first and second dimensions of the correspondence analysis of the frequency table of check-all-that-apply question. The plot is decluttered. Decluttered attributes (□): sweet, smooth, bright color, not floury flavor. (○): High floury flavor, low floury flavor, bad flavor, dark color, aftertaste, heterogeneous, not sweet.

Fig. 7. Representation of the terms in the first and second dimensions of the correspondence analysis of the frequency table of check-all- that- apply question and trend of overall liking. The plot is decluttered. Decluttered attributes: (○) low floury flavor, dark color, not sweet, lumpy, aftertaste, high floury flavor

creaminess in these samples. In addition, this is important to highlight that no significant differences were found in the frequency in which some of the attributes such as “aftertaste” and “floury flavor” were checked to describe the samples (data not shown). De Wijk *et al.* (2003) reported that two main sensory dimensions, one running from melting to thick and another one running from rough to creamy-soft, could be discerned in dairy desserts. The high number of mentions for the expression “nice

flavor” suggests that consumers liked the flavor of the majority of the desserts. It was found in the pretest that saffron and rosewater were suitable ingredients in this kind of dairy dessert to mask off-flavor and provide desirable flavor.

Results of overall liking (data not shown) revealed that sample 7 containing 10% flour, 8% inulin and 4% sugar was perceived as the least preferred as compared to the other samples. Producers should emphasize on the descriptors which negatively influence the

Table 5. Regression vector coefficients between sample configurations in the first two coordinates of principal component analysis for the two methodologies.

	Sensory (CATA)	Rheology	MFA
Sensory (CATA)	1.000	0.903	0.976
Rheology	0.903	1.000	0.975
MFA	0.976	0.975	1.000

Table 6. Coordinates of the methodologies in the multiple factor analysis carried out on consumers’ response to the Check-All-That-Apply (CATA) questions and rheological measurements.

	F1 (75.78%)	F2 (10.15%)
Sensory (CATA)	0.976	0.158
Rheology	0.978	0.103

Fig. 8. Comparative multiple factor analysis performed simultaneously on data from the two methodologies: consumers’ responses to the CATA (●) and rheological data (■)

cereal-based dairy desserts hedonic dimension, because these are possibly the most critical factors for consumer’s acceptability and as a result main purpose of buying. Our results revealed that fluid and not creamy make the desserts less pleasant for consumers. Sample 8 containing 16% flour, 6% inulin and 2% sugar was perceived as the most preferred, obtaining the highest mean score values for overall liking.

Correlation between rheological and sensory results For novel dairy dessert development it is important to accomplish the quantitative characterization of the rheological and sensory attributes of the product, and this can be achieved by using suitable methods of sensory evaluation and obtaining correlation between rheological and sensory results. In order to capture the relationship between consumers’ responses to the CATA and rheological data multiple factor analysis (MFA) was done. By using MFA it is conceivable to analyze various tables of variables concurrently (Pages and Husson, 2005). The CATA test consider both texture, appearance and flavor attributes as they have been recognized as the main drivers of liking in this product class, whereas rheological test just can accomplish the textural attributes, however, to obtain a

whole idea about distribution of samples and more perfect graphical comparison, appearance and flavor based attributes were also be inserted. According to the results, similar discriminative ability was found in two methods used in this research. Results obtained from consumers’ evaluation and from rheological data were compared by means of the regression vector (RV) coefficient (Table 5) (Perrin *et al.*, 2008). RV can be found out as a correlation coefficient in a multidimensional spaces, that lies between 0 and 1, the closer RV is to 1, the more similar the configurations of the two spaces are. As shown in Table 4, the RV coefficient between sample configurations from rheological and sensory methodologies was close to 1.

Coordinates of the two methodologies are displayed in table 6. The first two dimensions of the MFA explain 85.93% of the variance of the experimental data, displaying 75.78% and 10.15% of the variance for the first and second dimensions, respectively. As shown in table 6, from the standpoint of the first dimension the two methodologies were situated close to each other. It is important to remember that second dimension accounted for only 10.15% of variance and most of the variance was distinctly described by the

first dimension of the MFA. Figure 8 shows superimposed representation of the attributes evaluated by sensory method and rheological parameters. This map makes it possible to evaluate relationship between sensory attributes and rheological measurements. It is clear that attributes “creaminess” and “thickness” obtained from consumers’ perception were suited close to rheological parameters of storage modulus (G'), consistency (m) and apparent viscosity at 50 s^{-1} (η_{50}), suggesting a high correlation among these sensory attributes and above mentioned rheological parameter. The term fluid, evaluated by consumers, was highly correlated to loss tangent and flow index. Moreover, as shown in Figure 5, consumers’ perception of the term firm was correlated with apparent viscosity at 50 s^{-1} and G' . These results were in agreement with those published by other researchers (Ares *et al.*, 2012; Janssen *et al.*, 2007). Likewise, oral firmness, thickness and creaminess of desserts presented high correlation with yield stress values. These results were in correspondence with other researchers who reported that in food products with high viscosity or yield stress, thickness could be correlated with the force needed to generate considerable flow (van Vliet, 2002). In another study it was also concluded that the viscosity under steady shear at 10 s^{-1} had a good correlation with perceived thickness in semi-solid foods (Tárrega and Costell, 2007). Anyway it can be deduced that the initial resistance to flow (yield stress value) and apparent viscosity can be effective indicators of oral thickness for semi-solid desserts. Strong relationship was also detected amongst oral thickness and yield stress (τ_0) and apparent viscosity.

A combined analysis of rheological and sensory data revealed that samples with consistency (m) values lower than 7 Pa.s and with apparent viscosity (η_{50}) values lower than 1.31 Pa.s were those with the least desirable thickness and creaminess. Moreover, samples with loss tangent values in the range of $0.25 - 0.48$ were those with the most desirable thickness and creaminess. Finally, according to results from the present study samples 4, 6 and 8 that characterized instrumentally by attributes of high consistency, viscosity and elastic values showed the highest overall liking scores.

Conclusion

In this study a new dietary dairy dessert containing oat, wheat and corn flour, inulin and stevioside (as sugar substitute) was developed. A number of dessert samples formulated by mixture design approach exhibited appropriate sensory characteristics. These desserts besides having considerable lower sugar and fat compared to the commercial ones, still possessed functional properties. Moreover, our findings suggested that the evaluated CATA terms were able to identify differences in consumers’ perception of texture of the assessed cereal-based dessert. It was determined that sensory method using consumer perception could be valuable for development of functional dessert, which is very important in market succession. Results of this study provided

useful and practical information that could be effective in development of new dairy desserts.

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