Iranian J Publ Health, Vol. 42, No. 12, Dec 2013, pp.1446-1456

Original Article

Rheological Characterization and Cluster Classification of Iranian Commercial Foods, Drinks and Desserts to Recommend for Esophageal Dysphagia Diets

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(Received 22 Jun 2013; accepted 15 Sep 2013)

Abstract

Background: In the absence of dysphagia-oriented food products, rheological characterization of available food items is of importance for safe swallowing and adequate nutrient intake of dysphagic patients. In this way, introducing alternative items (with similar ease of swallow) is helpful to improve quality of life and nutritional intake of esophageal cancer dysphagia patients. The present study aimed at rheological characterization and cluster classification of potentially suitable foodstuffs marketed in Iran for their possible use in dysphagia diets.

Methods: In this descriptive study, rheological data were obtained during January and February 2012 in Rheology Lab of National Nutrition and Food Technology Research Institute Tehran, Iran. Steady state and oscillatory shear parameters of 39 commercial samples were obtained using a Physica MCR 301 rheometer (Anton-Paar, GmbH, Graz, Austria). Matlab Fuzzy Logic Toolbox (R2012 a) was utilized for cluster classification of the samples.

Results: Using an extended list of rheological parameters and fuzzy logic methods, 39 commercial samples (drinks, main courses and desserts) were divided to 5 clusters and degree of membership to each cluster was stated by a number between 0 and 0.99.

Conclusion: Considering apparent viscosity of foodstuffs as a single criterion for classification of dysphagia-oriented food products is shortcoming of current guidelines in dysphagia diets. Authors proposed to some revisions in classification of dysphagia-oriented food products and including more rheological parameters (especially, viscoelastic parameters) in the classification.

Keywords: Esophagus cancer, Esophageal dysphagia, Rheology, Diet, Food Industry

Introduction

Dysphagia is a prevalent symptom which is common in a wide range of diseases. Effects of dysphagia ranges from less-threatening conditions such as discomfort (e.g., chest pain) and psychological effects (such as embarrassment from coughing) to more severe conditions and illnesses such as choking, aspiration (the food entering the airway and passing the vocal folds), aspiration pneumonia, dehydration, malnutrition and even death (1).

In a general view, dysphagia is divided to oropharyngeal and esophageal dysphagia. In recent years, there has been an increasing interest in the treatment of oropharyngeal dysphagia and most researches have not dealt with the esophageal dysphagia (2-4).

One of main causes of esophageal dysphagia is the esophagus cancer. Esophageal cancer is the 6th most common cause of cancer death in the world (5). Golestan Province in northeastern Iran is one of the famous high-risk areas with the age standardized rates (ASR) of more than 100/-100000 (6, 7).

Several attempts have been made to the introduce strategies to the management of dysphagia. Logemann classified three basic types of dysphagia treatment strategies as behavioral, medical and surgical. He also claimed that behavioral treatments could be the first and easiest treatments (8). One of the important behavioral treatments is diet modification and using thickened foodstuffs to control the flow rate of foodstuffs. In developed countries, health-concerning food companies provide some choices (with certain rheological properties) for dysphagic patients and healthcare teams and families are supplied with these products.

If there are not proper choices and alternative items in the diet of dysphagic patients, they may get susceptible to undergo malnutrition and lack of micro and macronutrients may have negative effects on their health (9, 10).

Losing eating pleasure and social interaction is another negative consequence of impaired swallowing. Therefore, several studies have revealed that, in addition to physical health effects, dysphagia may lead to serious psychosocial and wellbeing problems, especially among the elderly (11). Dysphagia-oriented products are in two types of "ready-to-serve" and "powdered instant food thickener". From another viewpoint, dysphagia-oriented food products are classified into beverages, main courses, desserts and a new class which is called "pâté class"(12).

A notable part of the literature related to dysphagia has been devoted to proposing a united approach on dysphagia diets and foodstuffs. Having realized the need for standardization of dysphagia diet, miscellaneous practices have been performed and some manuals have been presented to the dietitians (13, 14).

In 2002, after these sporadic efforts, National Dysphagia Diet (NDD) was established by the American Dietetic Association and, nowadays, it seems to be the most practical guideline in many dysphagia-related papers (15-24). The NDD guideline proposed viscosity to range from thin (1-50 cP), nectar-thick (51-350 cP), honey-thick (351-1750 cP) to spoon thick (>1750 cP) foodstuffs. In this guideline, the measured viscosity at the shear rate of 50 (s^{-1}) is regarded as the criterion of dividing foodstuffs to the mentioned categories.

Most foodstuffs are viscoelastic materials, which cannot be fully characterized by ignoring the elastic component. Viscoelastic properties are particularly important for food processors in determining processing parameters, monitoring consistency and predicting stability of semi-solid food systems and final textural attributes of the formulated foods (25, 26). As in NDD, in most of dysphagia-rheology papers, the participation of elastic modulus in the characterization of foodstuffs and impact of this factor on swallowing process has been neglected.

Despite the high incidence rates of esophageal dysphagia in Iran, there is not any special industrial food product in the market for this group of patients. Moreover, the rheological data on traditional foodstuffs and even available items in the market is unavailable. Lack of this information may lead to having narrow range of food choices by dysphagic patients and nutritional staff.

While considering all the above mentioned points, flow and viscoelastic (strain sweep and frequency sweep) properties of semi-solid and liquid food stuffs presented in Iran market were analyzed. After extracting rheological data, to minimize volume of the data and give a general view, cluster classification of the data was performed. Finally, the place of samples in NDD categories was appointed.

The present study aimed at rheological characterization and cluster classification of potentially suitable foodstuffs marketed in Iran for their possible use in dysphagia diets. The presented data may help medical team and nutritional staff to choose proper items for dysphagia patient's menu.

Materials and Methods

All the food materials were purchased from a local supermarket (Tehran, Iran). In this descriptive study, data were obtained during January and February 2012 in rheology lab of National Nutrition and Food Technology Research Institute Tehran, Iran. The samples were selected from beverages (11 samples), main courses (8 samples) and desserts (20 samples). Rheological measurements were performed with a Physica MCR 301 rheometer (Anton-Paar, GmbH, Graz, Austria). Temperature control was carried out using a Peltier system equipped with a fluid circulator. The authors decided to perform rheological tests at temperatures which were special for serving each sample. Therefore, a clinical pretest was performed for each sample and the exact serving temperature was measured. These test temperatures are presented in Table 1.

For all the drink samples, concentric cylinder (CC27-SN16194; d=0 mm) geometry was utilized. The used geometry for main courses and dessert samples was the vane geometry (ST14-4V-35-SN16727; d=0 mm). Data analysis was carried out using Rheoplus software (version 3.21) (Anton Paar, Graz, Austria). Strain sweep tests were performed (0.01-1000%, 6.28 rad/s) to determine the limiting value of linear viscoelastic range (Lve). To provide a direct view for whether the samples behaved as liquids or solids, loss tangent was calculated at the Lve (ratio of loss modulus to elastic modulus). Crossover point (G'=G'') was also determined. Frequency sweep tests were performed using a frequency ramp from 0.0628 to 94.2 rad/s. Viscous and elastic modulies in three angular frequencies of 0.628, 1.84 and 17.4 (rad/s) were calculated as representatives of low, moderate and high angular frequencies, respectively.

Flow curves were obtained at shear rates of 0.01-1000 (1/s). The power law (over mid-range shear rates) model (Equation 1) was used to describe rheological properties of the samples. In the power law model, the flow behavior index (*n*) and consistency coefficient (*m*) values were obtained by fitting the shear rate versus apparent viscosity values.

$\eta_a = m\dot{\gamma}^{n-1}$ (Equation 1) Power law model

Where ηa is apparent viscosity (Pascal second), *m* is consistency coefficient (Pa.sn), $\dot{\gamma}$ is shear rate (1/s) and *n* is flow behavior index (dimensionless). When comparable parameters were obtained, Matlab Fuzzy Logic Toolbox (R2012 a) was utilized for clustering the samples.

Results

Rheological characterization

Fig. 1 only depicts the strain sweep rheograms of five representative samples. For the storage modulus (G') of thirty nine samples, it was possible to discriminate two different regions, namely, a linear viscoelastic region, in which G' was practically constant and a nonlinear region, in which G' started to diminish with increasing strain.

In the case of loss modulus (G''), the behavior of most samples in strain sweep test was identical to the one mentioned for G'. But, G'' of some samples like Ferni (Fig. 1) increased with increasing strain. In all the samples, both moduli finally tended to crossover; therefore, all 39 samples showed flow point. It is interesting to note that, in all 39 samples, before the flow point, G' was higher than G''; as a result, all the samples in the linear viscoelastic region showed a solid-like behavior. But, after the Lve, G'' was higher and the samples showed more liquid-like behavior. Strain sweep parameters of 39 samples are listed in Table 1.

Table 1: Strain sweep parameters of 39 samples. 1 and 2 indicate that rheological tests performed at 10 °C and 45 °C, respectively. Further rheological experiments were performed at the mentioned temperature, limiting value of linear viscoelastic range γ_l (%), damping factor for the end of Lve region tan δ_{Lve}, and crossover point G_f (pa) (G'=G") of samples

Type	Name	Brand	γ_l (%)	tan δ_{Lve}	G_f (pa)
Drinks	1. Guava Nectar[1]	Takdaneh®	5.55	0.82	0.25
	2. Apricot Nectar[1]	Takdaneh®	1.85	0.88	0.13
	3. Mango Nectar[1]	Shadlee®	3.84	0.56	0.28
	4. Peach Nectar[1]	Takdaneh®	2	0.44	0.32
	5. Apricot Nectar[1]	sunich®	1.85	0.38	0.40
	6. Mango Nectar[1]	Takdaneh®	3.17	0.3	0.45
	7. Peach-mango Nectar[1]	Shadlee®	1.99	0.3	0.82
	8. Cappochino coconut drink[1]	Danone sahar®	12.8	0.31	2.55
	9. Strawberry drink[1]	Danone sahar®	35.8	0.76	0.62
	10. Melone drink[1]	Danone sahar®	27.4	0.68	0.91
	11. chocolate coconut[1]	Danone sahar®	23.6	0.24	4.70
Main courses	12. Halim[2]	Kamchin®	7.13	0.23	111.39
	13. Halim[2]	Elit®	0.47	0.241	22.89
	14. Sholezard[1]	Kalleh®	8.2	0.32	192.38
	15. Shirberenj[1]	Kalleh®		0.42	31.86
	16. Vegetable soup[2]	Knorr®	0.12	0.31	13.02
	17. Chicken soup[2]	Sabzan®	4.56	0.26	5.80
	18. Lentile soup[2]	Elite®	1.34	0.32	5.81
	19. Eggplant dish[2]	Sahar®	1.69	0.25	44.61
Desserts	20. Fig olive yoghurt[1]	Kalleh®	10.6	0.2	42.54
	21. Spinach yoghurt (Boorani)[1]	Kalleh®	9.45	0.2	16.998
	22. Celery yoghurt[1]	Kalleh®	4.44	0.25	8.75
	23. Cucumber yoghurt[1]	Kalleh®	3.64	0.23	30.04
	24. Seven yoghurt[1]	Kalleh®	13.8	0.21	16.86
	25. Ferni[1]	Haraz®	33.4	0.19	75.87
	26. Saffron dessert[1]	Kalleh®	12.8	0.19	67.69
	27. Coffee dessert[1]	Kalleh®	14.6	0.2	71.32
	28. Chocolate dessert[1]	Danone sahar®	33.6	0.21	23.34
	29. Banana dessert[1]	Danone sahar®	38.6	0.23	21.78
	30. Vanilla dessert[1]	Danone sahar®	43.4	0.21	24.76
	31. Biscuit dessert[1]	Danone sahar®	29.7	0.26	21.44
	32. Strawberry dessert[1]	Danone sahar®	34.4	0.26	14.76
	33. Caramel dessert[1]	pakban®	71.1	0.28	21.32
	34. Cocoa cream dessert[1]	pakban®	9.46	0.23	96.49
	35. Aloevera yoghurt[1]	kalleh®	8.6	0.21	21.08
	36. Apple yoghurt[1]	kalleh®	10.1	0.2	15.43
	37. Peach yoghurt[1]	kalleh®	17.2	0.21	26.70
	38. Strawberry yoghurt[1]	kalleh®	7.61	0.23	20.93
	39. fig Cream[1]	kalleh®	0.22	0.23	93.01

Considering strain sweep, frequency sweep tests were performed and mechanical spectra of five representative samples is depicted in Fig. 2 and Table 2 presents the viscous and elastic modulies of 39 samples in three angular frequencies of 0.628, 1.84 and 17.4 (rad/s). The power law model (Equation 1) parameters for 39 samples are given in Table 3. These parameters were calculated within 10-200 (1/s).

The coefficients of determination (R^2) were 0.99 or higher for all the tested samples, indicating appropriateness of the power law model to describe flow properties of different samples.

Table 2: Frequency sweep parameters of 39 samples, G'(Pa) and G" (Pa) of each sample in frequency sweep test was calculated in three angular frequencies, namely, low ω= 0.0628 (rad/s), medium ω= 1.84 (rad/s) and high ω= 17.4 (rad/s) angular frequencies

Name		G'(Pa) :			G"(Pa):	
	ω=(0.0628)	ω= (1.84)	ω= (17.4)	ω= (0.0628)	ω= (1.84)	ω= (17.4)
1. Guava Nectar (Takdaneh®)	0.22	0.24	0.24	0.04	0.12	0.52
2. Apricot Nectar (Takdaneh®)	0.10	0.11	0.12	0.01	0.06	0.31
3. Mango Nectar (Shadlee®)	0.37	0.41	0.51	0.04	0.14	0.58
4. Peach Nectar (Takdaneh®)	0.56	0.55	0.60	0.07	0.17	0.66
5. Apricot Nectar (sunich®)	0.74	0.74	0.83	0.08	0.21	0.76
6. Mango Nectar (Takdaneh®)	0.90	0.99	1.12	0.10	0.23	0.82
7. Peach-mango Nectar (Shadlee®)	2.09	2.13	2.55	0.26	0.49	1.45
8. Cappochino coconut drink (Danone sahar®)	5.16	8.75	7.63	1.21	2.37	4.79
9. Strawberry drink (Danone sahar®)	0.63	1.45	1.62	0.20	0.54	3.61
10. Melone drink (Danone sahar®)	1.2	2.65	2.87	0.39	0.81	4.42
11. Chocolate coconut (Danone sahar®)	15.8	23.2	29.2	3.27	4.1	7.99
12. Halim (Kamchin®)	617	806	1010	116	151	240
13. Halim (Elit®)	41.4	45.5	62.6	14.7	19.5	29.9
14. Sholezard (kalleh®)	470	665	919	97.2	167	269
15. Shirberenj (kalleh®)	64.8	104	160	19.8	37.6	70.7
16. Vegetable soup (Knorr®)	17.5	19	28.7	11.6	17.6	28.6
17. Chicken soup (sabzan®)	15.4	15.7	17.3	2.68	3.32	7.28
18. Lentile soup (Elit®)	14.7	15.8	18.3	2.96	5.03	10.3
19. Eggplant dish (Sahar®)	531	645	859	91.1	164	224
20. Fig olive yoghurt (kalleh®)	194	322	415	49.3	64.3	87.2
21. Spinach yoghurt (kalleh®)	96.5	171	226	31.8	39.8	54.4
22. Celery yoghurt (kalleh®)	39.7	59.6	68.5	13.9	16.8	23
23. Cucumber yoghurt (kalleh®)	174	296	383	61.3	75.6	94.5
24. Seven yoghurt (kalleh®)	76.1	132	170	22.4	27.6	36.5
25. Ferni (Haraz®)	238	290	340	29	37	52.2
26. Saffron dessert (kalleh®)	259	259	325	401	39.7	49.2
27. Coffee dessert (kalleh®)	251	251	320	384	41.9	48.1
28. Chocolate dessert (Danone sahar®)	86.6	122	145	15.4	17.4	28.5
29. Banana dessert (Danone sahar®)	53.9	74.5	89.9	9.93	12.6	21
30. Vanilla dessert (Danone sahar®)	78.9	110	133	12.4	15.9	26
31. Biscuit dessert (Danone sahar®)	65.1	83.3	97.9	11.3	14.4	25.3
32. Strawberry dessert (Danone sahar®)	38.3	56.3	67	8.37	10.7	18.5
33. Caramel dessert (Pakban®)	41.3	117	151	7.95	17.9	28.8
34. Cocoa cream dessert (Pakban®)	397	883	1220	110	197	267
35. Aloevera yoghurt (kalleh®)	99.8	169	224	29.7	37.6	51.5
36. Apple yoghurt (kalleh®)	70.1	113	145	25	25.7	31.1
37. Peach yoghurt (kalleh®)	137	230	308	35.6	50	67.1
38. Strawberry yoghurt (kalleh®)	113	189	253	34.2	45.6	61.8
39. Fig Cream (kalleh®)	866	1090	1310	365	465	591

All 39 samples showed a non-Newtonian flow or pseudoplasticity. As the shear rate increased, apparent viscosity of all the samples decreased. This result was similar to that of previous studies on dysphagia-oriented products (27, 28, 29). Apparent viscosity at the shear rate of 50 (s^{-1}) was also reported (Table 3).

Cluster classification of the samples

Using clustering, a large number of samples were classified into clusters in which all cluster members were similar to each other and were different from those of other clusters (30). Clustering started by Fuzzy Logic Toolbox MATLAB (R2012 a) and subtractive clustering technique was employed as the clustering method (31). Cluster classification of 39 samples performed by the use of 3 strain sweep parameters (Lve (%), tan Lve and G'=G" (pa)), 6 frequency sweep parameters (G': ω= (0.0628, 1.84, 17.4 rad/s, G": ω= (0.0628, 1.84, 17.4 rad/s) and 2 steady state parameters (m,η_{50}). Considering this procedure, the samples were classified into 5 clusters. Table 4 shows the membership degree of each sample to clusters.

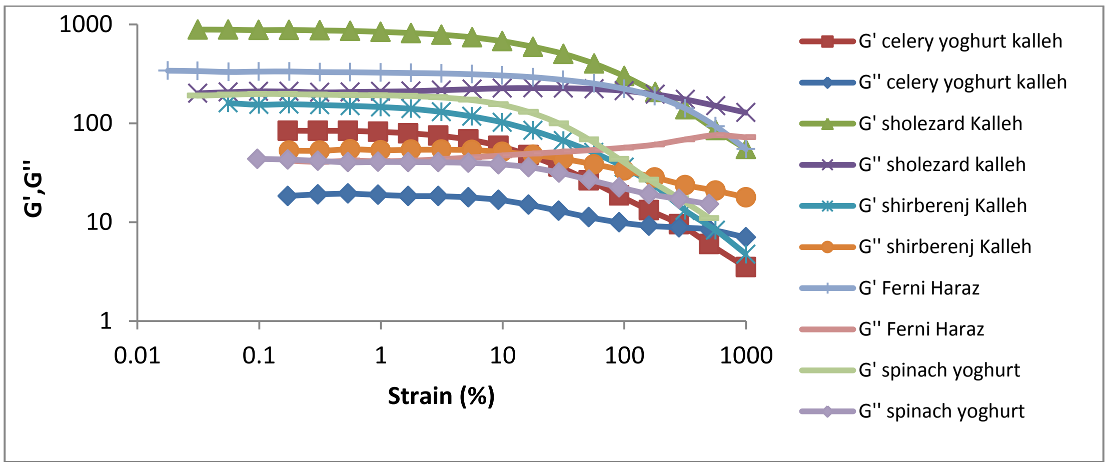

Fig. 1: Strain sweep of five representative samples

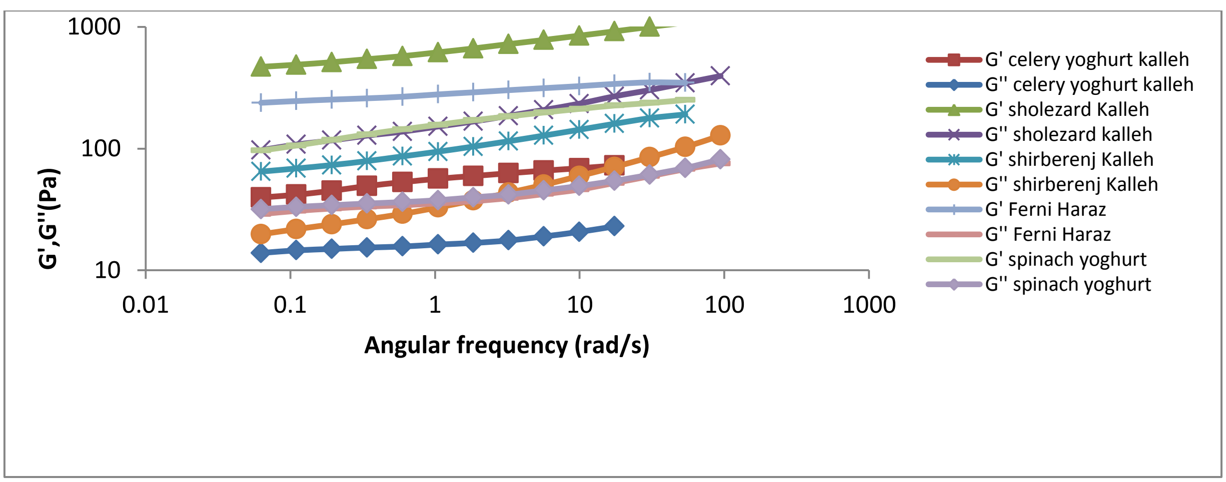

Fig. 2: Frequency sweep rheogram of five representative samples

Discussion

One of the main goals of the present study was rheological identification of available food, drinks and desserts in Iranian market and comparing the data with NDD. Seven products, all of which were fruit juices classified into non-thickened group of NDD (η= 0-50 Pa.s).

This indicates that use of these items may increase risk of aspiration among dysphagic patients and should not be advised to patients without any thickening agents.

Table 3: Power-law model parameters and apparent viscosity of 39 samples

Name	Power law model		Apparent viscosity
	m(Pas^n)	n	(cP)
1. Guava Nectar (Takdaneh®)	0.08	0.56	14.71
2. Apricot Nectar (Takdaneh®)	0.05	0.56	9.31
3. Mango Nectar (Shadlee®)	0.1	0.53	16.01
4. Peach Nectar (Takdaneh®)	0.15	0.46	18.36
5. Apricot Nectar (sunich®)	0.15	0.45	17.71
6. Mango Nectar (Takdaneh®)	0.18	0.45	21.69
7. Peach-mango Nectar (Shadlee®)	0.31	0.41	30.64
8. Cappochino coconut drink(Danone sahar®)	10.53	0.25	589.04
9. Strawberry drink (Danone sahar®)	1.6	0.43	163.14
10. Melone drink (Danone sahar®)	2.95	0.38	251.81
11. chocolate coconut (Danone sahar®)	18.92	0.23	919.67
12. Halim (Kamchin®)	164.57	0.24	8455.03
13. Halim (Elit®)	5.64	0.37	451.15
14. Sholezard (kalleh®)	347	0.28	20780.16
15. Shirberenj (kalleh®)	40	0.41	3911.92
16. Vegetable soup (Knorr®)	3.33	0.39	281.41
17. Chicken soup (sabzan®)	10.85	0.29	645.18
18. Lentile soup (Elit®)	19.1	0.19	736.37
19. Eggplant dish (Sahar®)	95	0.12	2691.79
20. Fig olive yoghurt (kalleh®)	72.32	0.25	3591.35
21. Spinach yoghurt (kalleh®)	37.14	0.24	1825.83
22. Celery yoghurt (kalleh®)	16	0.31	1069.39
23. Cucumber yoghurt (kalleh®)	34	0.33	2466.97
24. Seven yoghurt (kalleh®)	25.49	0.28	1504
25. Ferni (Haraz®)	336	0.18	9818.05
26. Saffron dessert (kalleh®)	293.15	0.15	10270.45
27. Coffee dessert (kalleh®)	361.07	0.13	11635.63
28. Chocolate dessert (Danone sahar®)	99.4	0.2	4188.36
29. Banana dessert (Danone sahar®)	96.15	0.2	4017.8
30. Vanilla dessert (Danone sahar®)	124.12	0.17	4538.02
31. Biscuit dessert (Danone sahar®)	91.41	0.22	4204.23
32. Strawberry dessert (Danone sahar®)	66.87	0.22	3057.89
33. Caramel dessert (Pakban®)	73.72	0.17	2691.79
34. Cocoa cream dessert (Pakban®)	349.14	0.17	13283.19
35. Aloevera yoghurt (kalleh®)	19.54	0.4	1685.45
36. Apple yoghurt (kalleh®)	21.82	0.32	1440.95
37. Peach yoghurt (kalleh)	56.88	0.26	3009.4
38. Strawberry yoghurt (kalleh)	31.89	0.32	2122.11
39. Fig Cream (kalleh®)	97.47	0.33	7013.89

The absence of prethickened fruit juices makes a niche market for health conscious companies to provide nutritional needs of dysphagic patients. Previous studies have reported that providing dysphagic patients with thickened liquids has positive effects on hydration and life quality of patients through inhibition from aspiration (3). Thicker fluids in comparison to thin-liquid boluses will support airway protection through one or more of several mechanisms including increased sensory feedback, increased bolus cohesiveness and/or decelerated bolus flow through the oropharynx (32). Moreover, studies have shown that, when patients have access to thickened fluids, better hydration is obtained.

Table 4: Membership degree of 39 samples to each cluster

Name	Cluster				
	1	2	3	4	5
1. Halim (Elit®)	0.99	0	0	0	0
2. Vegetable soup (Knorr®)	0.99	0	0	0	0
3. Strawberry drink (Danone sahar®)	0.99	0	0	0	0
4. Melone drink (Danone sahar®)	0.99	0	0	0	0
5. Apricot Nectar (Takdaneh®)	0.97	0	0.01	0	0
6. Mango Nectar (Shadlee®)	0.97	0	0.01	0	0
7. Peach Nectar (Takdaneh®)	0.97	0	0.01	0	0
8. Apricot Nectar (sunich®)	0.97	0	0.01	0	0
9. Mango Nectar (Takdaneh®)	0.97	0	0.01	0	0
10. Peach-mango Nectar (Shadlee®)	0.97	0	0.01	0	0
11. Guava Nectar (Takdaneh®)	0.97	0	0.01	0	0
12. Cappochino coconut drink (Danone sahar®)	0.96	0	0.02	0	0
13. Chicken soup (sabzan®)	0.95	0	0	0	0
14. Lentile soup (Elit®)	0.91	0	0.06	0	0.01
15. Chocolate coconut (Danone sahar®)	0.80	0	0.15	0	0.02
16. Celery yoghurt (kalleh®)	0.68	0	0.26	0	0.04
17. Sholezard (kalleh®)	0	0.99	0	0	0
18. Strawberry yoghurt (kalleh®)	0	0	0.98	0	0
19. Cucumber yoghurt (kalleh®)	0.01	0	0.96	0	0.02
20. Spinach yoghurt (kalleh®)	0.07	0	0.89	0	0.03
21. Caramel dessert (Pakban®)	0.03	0	0.86	0	0.09
22. Aloevera yoghurt (kalleh®)	0.1	0	0.81	0	0.04
23. Eggplant dish (Sahar®)	0.08	0	0.69	0	0.2
24. seven yoghurt(Kalleh®)	0.2	0	0.67	0	0.05
25. Peach yoghurt (kalleh®)	0.05	0	0.65	0	0.28
26. Apple yoghurt (kalleh®)	0.32	0	0.61	0	0.05
27. Strawberry dessert (Danone sahar®)	0.05	0	0.58	0	0.34
28. Saffron dessert (kalleh®)	0	0	0	0.98	0
29. Ferni (Haraz®)	0	0	0.01	0.94	0.02
30. Coffee dessert (kalleh®)	0	0.01	0.01	0.94	0.01
31. Cocoa cream dessert (Pakban®)	0.03	0.1	0.04	0.74	0.06
32. Halim (Kamchin®)	0.05	0.02	0.08	0.66	0.17
33. Biscuit dessert (Danone sahar®)	0	0	0	0	0.99
34. Chocolate dessert (Danone sahar)	0	0	0	0	0.99
35. Banana dessert (Danone sahar®)	0	0	0.01	0	0.98
36. Shirberenj (kalleh®)	0	0	0.02	0	0.96
37. Vanilla dessert (Danone sahar®)	0	0	0.02	0	0.95
38. Fig olive yoghurt (kalleh®)	0.02	0.01	0.17	0	0.78
39. Fig Cream (kalleh®)	0.09	0.02	0.17	0.3	0.39

Garon reported more satisfaction and low aspiration in stroke patients which had dysphagia and aspiration (compared with the control group) when thickened fluids were accessible (33). Table 3 shows that only three products are located in the nectar consistency class of NDD (η= 50-350 Pa.s), which include two drinks (strawberry drink and melon drink) and one soup (vegetable soup) samples. In the honey consistency class (η= 350-1750 Pa.s), there is at least one sample from dessert, main course and drinks. And finally, most of the samples are located in spoon thick class (η= 350-1750 cP).

It seems that some items in the spoon thick class (1825.83-20780.16 cP) have viscosity values more than the normal designed foods of this category. For example, in the study by Germain, in spoon thick category items, viscosity at shear rate of 50 (s^{-1}) ranged from 1750 (vegetable juice) to 4880 (prune juice) (27). Quinchia et al. reported that the apparent viscosity of a strawberry flavored pudding (which was designed for dysphagic patients) at the shear rate of 50 (s^{-1}) was 5000 cP (28). It is interesting to note that the "Sholezard" sample had the highest apparent viscosity (20780.16 Pa.s) among the samples. Dysphagic patients need thicker boluses but is there any limit for this "thicker boluses"? In other words, do thicker boluses always lead to safe swallow? There are some reports that claim very thick boluses lead to food refusal by dysphagic patients (14).

As mentioned before, NDD classes are based on the only apparent viscosity at the shear rate of 50 (s^{-1}). When the classification of dysphagia-oriented products is performed by more factors (especially, viscoelastic parameters), like the experience of casanovas (12), a fifth class is added to conventional classes which is called "pate class". In the present work, the "Sholezard" sample (which had the highest apparent viscosity) could be located in this class.

In the current study, based on the classification method (NDD or cluster classification), there was some differences between the numbers of members in the classes. For example, as mentioned before, non-thickened group of NDD in this study contained all seven nectars. As shown in Table 4, class 1 of cluster classification consisted of these seven nectars in addition to nine other samples. Therefore, when more rheological parameters were involved in classification, NDD categories became imprecise to define all classes and the place of some samples probably changed. Such variations were observed in other classes, which indicated that effect of including viscoelastic parameters of foodstuffs should be investigated on NDD categories.

The key problem with NDD classification is that some hydrocolloid solutions show different swallowing profiles in a fixed shear viscosity. For example, in an equivalent shear viscosity (at 10 s^{-1}), xanthan gum and locust bean gum show different swallowing profiles; therefore, the only viscosity at a certain shear rate does not completely represent ease of swallowing (34, 35). Moreover, this view was supported by Kumagai (2011) who introduced some viscoelastic parameters as suitable parameters for characterizing both liquid- and gel-like dysphagia-oriented products.

Taken together, the findings of this study suggested that further clinical trials are required to introduce the most effective rheological parameters for attaining a safe swallow and achieving a proper basis for classification of dysphagia-oriented products.

Comparing the obtained data from the present study with NDD guidelines, it is obvious that, in the Iranian market, there are some food products in each class of NDD. Therefore, nutritional staff in healthcare systems could add some items to diet of dysphagic patients by the presented data. Furthermore, some of these items could be attained in the dysphagic diets by some rheological modification. It is worth pointing out that the exact clinical importance of these data should be proved using precise clinical trials with different types of dysphagia.

Conclusions

Some Iranian food products were evaluated with respect to National Dysphagia Diet guideline and few products in each class of NDD were introduced. NDD guideline presented a four-category classification of dysphagia-oriented food products just based on a single rheological parameter, viscosity. In the present study, using cluster classification technique and considering both steady shear and oscillatory rheological parameters the samples were classified into five distinct groups.

The results of this classification encourage further research to develop food-based solutions for dysphagia. On the other hand, the food industries can use this research in the development of traditional food products that are intended for dysphagic patients.

Ethical considerations

Ethical issues (Including plagiarism, Informed Consent, misconduct, data fabrication and/or falsification, double publication and/or submission, redundancy, etc.) have been completely observed by the authors.

Acknowledgements

This paper is a part of a larger research project for identifying and modifying rheological properties of beverages, desserts and food in patients with esophagus cancer dysphagia and assessing the effect of rheological modification on improving nutritional indices and quality of life in these patients, supported by National Nutrition and Food Technology Research Institute (NNFTRI). The authors declare that there is no conflict of interest.

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