Determination of relationship between sensory viscosity rating and instrumental flow behaviour of soluble dietary fibers

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Abstract The shear-thinning low, medium and high-viscosity fiber preparations (0.15–1.05 % psyllium husk, 0.07–0.6 % guar gum, 0.15–1.20 % gum tragacanth, 0.1–0.8 % gum karaya, 0.15–1.05 % high-viscosity Carboxy Methyl Cellulose and 0.1–0.7 % xanthan gum) showed that the consistency coefficient (k) was a function of concentration, the relationship being exponential (R^2 , 0.87–0.96; $P < 0.01$). The flow behaviour index (n) (except for gum karaya and CMC)

was exponentially related to concentration (R^2 , 0.61–0.98). The relationship between k and sensory viscosity rating (SVR) was essentially linear in nearly all cases. The SVR could be predicted from the consistency coefficient using the regression equations developed. Also, the relationship of k with fiber concentration would make it possible to identify the concentration of a particular gum required to have desired consistency in terms of SVR.

Highlights

- The shear-thinning low, medium and high-viscosity fiber preparations (0.15–1.05 % psyllium husk, 0.07–0.6 % guar gum, 0.15–1.20 % gum tragacanth, 0.1–0.8 % gum karaya, 0.15–1.05 % high-viscosity CMC and 0.1–0.7 % xanthan gum) showed that the consistency coefficient (k) was a function of concentration, the relationship being exponential (R^2 , 0.87–0.96; $P < 0.01$).
- The flow behaviour index (n) for psyllium husk, guar gum, gum tragacanth, 0.1- and xanthan gum was exponentially related to concentration (R^2 , 0.61–0.98).
- The relationship between k and sensory viscosity rating (SVR) was essentially linear in nearly all cases.
- The SVR could be predicted from the consistency coefficient using the regression equations developed.
- The relationship of k with fiber concentration would make it possible to identify the concentration of a particular gum required to have desired consistency in terms of SVR.

Keywords Soluble dietary fiber · Sensory viscosity rating · Instrumental viscosity · Flow behavior index · Psyllium husk · Guar gum · Tragacanth · Xanthan gum · Gum karaya · Carboxy Methyl Cellulose

Introduction

Based on solubility in water, dietary fiber is categorized as ‘insoluble’ and ‘soluble fiber’. Soluble fiber dissolves in water forming highly viscous fluid or gel. The high viscosity is responsible for the modified intestinal motility and delayed absorption of glucose in the intestines (Topping 2013). This property is beneficial for regulation of blood glucose and of appetite, and may also reduce the quantity of bile acids reabsorbed. The role of gums in satiety/satiation in formulated foods has been reviewed by Fiszman and Varela (2013). This high viscosity is also believed to reduce the serum cholesterol and triglyceride levels, and increase the high density lipoprotein (HDL), or (good cholesterol) level, thus acting against hypercholesterolemia (Allen 2013; Anderson et al. 1991 and Craig et al. 1999). Examples of soluble fibers include gums (plant extracts), pectins, mucilages, galactomannans,

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arabinogalactans, beta-glucans, non-digestible oligosaccharides and non-starchy water-soluble polysaccharides containing hemicelluloses.

A major class of soluble fiber ingredients is hydrocolloids, frequently referred to as gums. These compounds are polysaccharides that dissolve or disperse in water to give a thickening effect resulting in gel formation or increased viscosity (Cui et al. 2011). As food additives, these are used to stabilize emulsions, suspend particulates, control of crystallization, inhibition of syneresis, encapsulation, formation of films (Amiri et al. 2015; Cui et al. 2011; Phillips and Williams 2009; Waldt 1961, and Werbin 1953) and the reduced cooking loss in noodles (Kaur et al. 2015). They are classified as “generally recognized as safe” (GRAS) substances by the US Food and Drug Administration. Their permissible use levels and limitations in various products are covered under Title 21CFR Part 184.

Gums include plant exudates such as gum Arabic (also known as gum Acacia, the exudate of the tree *Acacia* species, primarily *Acacia senegal*), gum karaya (also called Indian tragacanth, is an exudate of the tree *Sterculia* species) and gum tragacanth (a plant exudate collected from *Astragalus* species shrub), seed gums such a guar gum (obtained from the seed endosperm of the leguminous plant *Cyamopsis tetragonoloba*); psyllium (obtained from Ispaghula seed husk, *Plantago ovata* Forsk.), and algal or microbial polysaccharides such as xanthan gum (the extracellular polysaccharide of the microorganism *Xanthomonas campestris*) (Belitz and Grosch 1999).

Inulin is a non-digestible oligosaccharide. Non-digestible oligosaccharides are complex carbohydrates which are resistant to hydrolysis by acid and enzymes in the human digestive tract due to the configuration of their glycosidic bonds e.g. fructooligosaccharides (FOS) including inulin and oligofructose; palatinose condensates (PC) including polydextrose, pyrodextrins, sololigosaccharides and xylooligosaccharides (Roberfroid 1999). Fructooligosaccharides are naturally found in foods such as garlic, onion, leek, asparagus, banana and wheat. If the degree of polymerization (DP) is <9, then they are termed as oligofructose, and with an average DP between 12 and 60 are termed as inulin. Inulin is obtained by hot water extraction of chicory root and as such is an ingredient in a number of food products due to its fat-like properties and its sweet taste (one-third of the sweetness of sugar).

Viscosity (resistance to flow) is caused by physical interactions between polysaccharide molecules of soluble dietary

fiber in solution. At low concentration, the molecules are well separated from each other and free to move independently. At a critical concentration (C^*) the molecules become sufficiently crowded to start to interpenetrate and form a tangled network. The viscosity then increases sharply with concentration and becomes more dependent on the rate of shear. Polysaccharides solutions thus usually show “shear thinning” i.e., the apparent viscosity decreases with increasing rate of shear (Thibault et al. 1992). In dilute solutions, i.e. at concentrations below the onset of entanglement ($C < C^*$), viscosity is only slightly dependent on the rate of shear. The solution exhibits a Newtonian Flow behavior at further very low concentrations, it means that the viscosity does not change with the increase or decrease of shear rate (Phillips and Williams 2009). However, at concentrations above the onset of entanglement ($C > C^*$), these entanglements have to be ripped apart for the solution to flow. At high shear rate, the rate of reentanglement is slower than the rate of entanglement and the viscosity decreases (Oakenfull 2001). Most of the shear-thinning gum solutions exhibit power-law flow behaviour. The power-law parameters of various gum solutions at high concentrations (to cause thickening or gelling effects) have been reported by Moskowitz (1972); Marcotte et al. (2001) and Cevoli et al. (2013). The complexity of food oral processing in relation to rheology and mechanical properties of food has been reviewed in detail by Chen (2009) and Mudgil et al. (2014) has reviewed the factors like temperature, solute, pH and concentration affecting the viscosity and hydration rate of guar gum.

Soluble dietary fiber could be of use in beverages or liquid products like liquid milk. To have established benefits from the consumption of soluble dietary fibers, it requires higher doses to be used in a meal/drink than those commonly employed to stabilize or improve the texture of food systems. But adding large quantities of viscous gums to drinks/beverage/milk products can affect the sensory properties, with consequences such as unpleasant degree of thickness or a slimy mouthfeel making them difficult to swallow. Little work has been done on the properties of gums at such low concentrations at which they produce very little or almost negligible effect on the viscosity of the water or water-like-liquid products. Thus some difficulties may be expected from the uncertainty in the behavior of these gums in beverage or liquid milk, for example. However, as more and more manufacturers are interested to incorporate the soluble dietary fiber along with some insoluble dietary fiber as a healthful ingredient into their products to have ‘value addition’ but with minimum of changes in the rheological properties of product, it becomes essential to know the relation between the sensory viscosity rating (SVR) and the flow

Table 1 Sensory viscosity rating (SVR) of soluble fibers dispersed in water at relatively high concentrations

S. No.	Name of soluble fiber	Conc. (%)	SVR [†]	Remark
1.	Gum Acacia	10.00	90	Slightly translucent solution
		15.00	86	
		20.00	76	
2.	Inulin	15.0	76	Milky white dispersion, tending to gel at higher concentrations
		20.00	25	
		25.00	10	
3.	Tragacanth	0.75	36	Flowable, sedimentation
		1.0	25	
		1.25	12	
4.	CMC, low viscosity	1.50	39	Clear transparent solutions
		1.75	44	
		2.00	23	
5.	CMC, high viscosity	1.00	50	Nearly clear to translucent solutions
		1.25	17	
		1.50	0	
6.	Gum karaya	1.00	10	Turbid
		1.25	3	
7.	Guar gum	1.50	0	Yellowish-grey, translucent, turbid gel; on stirring: not flowable
		2.00	0	
8.	Psyllium husk, powdered*	1.00	3	Turbid, whitish, translucent solution; on stirring: air incorporation but flowable: 1.25 and 1.5 % were non redispersible gel
		1.25	0	
		1.50	0	
9.	Xanthan gum	1.00	1	Turbid, not flowable
		1.25	0	

*Dried at 105 °C/30 min, ground in the Cyclotech grinder; blended for 5 min in hand blender ‘Yamaha’ at speed ‘I’

[†] Vide Appendix A

behavior of the soluble fiber (s) at low concentrations. Therefore, this study has been undertaken to develop better understanding about the rheological behavior of soluble dietary fiber disperse in water selected at levels determined from preliminary laboratory trials at which they might bring very less viscosity change in the liquid food product thus helping in the development of healthy new food products in order to meet the growing demand for healthful products for largely aware consumers.

Materials and methods

Commercial soluble fiber preparations

Soluble fiber preparations like Xanthan gum, gum Acacia /gum Arabic, gum Tragacanth, gum Guar, gum Karaya were purchased from MP Biomedicals (Span), USA; Carboxy methyl cellulose (sodium salt) – High viscosity was purchased from Loba Chemie, Mumbai, India; Carboxy methyl cellulose (sodium salt) – Low viscosity was purchased from CDH, New

Delhi, India; Psyllium (*Plantago ovata*) husk: ‘Sat Isabgol’ was obtained from Sidhpur/Palani Group, Mumbai, India; Inulin (Raftiline ST) make ORAFTI (Belgium) was purchased from S. A. Pharmachem, Mumbai, India and sugar was obtained from the local market.

Preparation of fiber dispersions

Initially the concentrated solutions were prepared (levels are detailed in Table 1) in order to find the suitable range of concentrations for each gum at which these gums/soluble dietary fibers would give an upper viscosity limit tolerable to drink/ swallow. The upper concentration limit was worked out from the SVR and the suitable range of concentrations to study flow curve parameters for each soluble fiber were determined as can be studied with the Viscostar plus model L viscometer at the selected shear rates. Psyllium husk was used in ground form. Cyclotech 1093 sample mill (*Foss Techator*, Sweden) fitted with a 0.5 mm sieve was used to grind the psyllium husk (predried at 105 °C/30 min) into a fine powder. Individual soluble fiber preparations were dispersed in distilled water at

selected concentrations viz., guar gum, Arabic/acacia gum, xanthan gum, karaya gum, tragacanth gum, inulin, CMC (high viscosity), CMC (low viscosity) and ground psyllium husk were weighed into glass beakers, dry mixed with ground sugar (5.0 %) and dispersed in agitated distilled water (except psyllium husk) on magnetic stirrer 'SpinIt' using a small size (30 mm × 6 mm) magnetic bar at speed '7'. After the complete transfer of weighed quantity of fiber into the water, the speed of the stirrer was increased to '10' and the solution was stirred for another five minutes or till complete dissolution. Psyllium husk dispersion was blended using a wet hand blender make 'Yamaha' at speed I for 5 min.

Determination of sensory viscosity rating (SVR)

The prepared samples were kept in a refrigerator (5 ± 1 °C) for overnight, followed by tempering to

room temperature. The tempered dispersions were examined for sensory viscosity rating (SVR) on the 10 cm long structured linear (vertical) scale (vide Annexure-A) by trained sensory panel.

Measurement of apparent viscosity and rheological properties

The samples were examined for the apparent viscosity using Viscostar Plus model L viscometer (*Fungilab*, Spain) at 20 ± 1 °C. It is provided with the different attachments viz., LCP (small sample adapter), APM assembly of coaxial cylinders (spindles TL-5, TL-6, TL-7) and Heldal unit with T-shaped spindles (PA, PB, PC, and PD). In the present study the attachments used were LCP (small sample adapter) and APM assembly of coaxial cylinders (spindles TL-5, TL-6, TL-7). Specifically, for gum

Fig. 1 Shear stress vs. shear rate relationship of different low- and medium- viscosity gums

Fig. 2 **a** Shear stress vs. shear rate relationship of different high-viscosity gums. **b** Shear stress vs. shear rate relationship of different high-viscosity gums

Table 2 Concentration-dependent flow-curve parameters of low- and medium-viscosity soluble fiber preparations dissolved in water (20 °C)

Sr. No.	Fiber preparation	Conc. range (%) [C]	Power law parameter	Consistency coefficient (k) mPa.s ⁿ	Flow behaviour index (n)	Regression on C				Appropriate Regression equation	
						k vs. C or n vs. C		Linear		Exponential	
						R	R ²	R	R ²	R	R ²
1.	GumAcacia	3–21	118.5–193.4		0.14–0.47	k vs. C	0.9623	0.93	0.9709	0.94	$k = 111.28e^{0.0251C}$
						n vs. C	0.8344	0.70	0.7896	0.62	$n = 0.1606\ln(C) - 0.0012$
2.	Inulin	2.75–16.50	110.5–398.9		0.18–1.10	k vs. C	0.9012	0.81	0.9323	0.87	$k = 71.247e^{0.0999C}$
						n vs. C	0.6278	0.39	0.6046	0.37	-
3.	CMC, low viscosity	0.25–1.75	221.4–1288.0		0.34–0.60	k vs. C	0.9751	0.95	0.9781	0.96	$k = 200.27e^{1.0903C}$
						n vs. C	0.9367	0.88	0.9540	0.91	$n = 0.1635C + 0.271$

Table 3 Concentration-dependent flow-curve parameters of high-viscosity fibers in water (20 °C)

Sr. No.	Fiber preparation	Concentration (C) range	Power law parameters		Regression on C				Appropriate regression equation	
			k	n	Linear		Exponential			
					R	R ²	R	R ²		
1.	Psyllium husk	0.15–1.05	250.5–1173.5	0.13–0.44	k vs. C	0.9623	0.93	0.9909	0.98	$k = 183.68e^{1.7253C}$
					n vs. C	0.9636	0.93	0.9865	0.97	$n = 0.356C + 0.03$
2.	Guar gum	0.07–0.6	61.7–908.7	0.18–0.64	k vs. C	0.8996	0.81	0.7833	0.61	$k = 365.44\ln(C) + 1057.9$
					n vs. C	0.9556	0.91	0.9678	0.94	$n = 0.8765C + 0.0666$
3.	Gum tragacanth	0.15–1.2	130.0–1157.2	0.41–0.75	k vs. C	0.9377	0.88	0.9783	0.96	$k = 107.74e^{1.9583C}$
					n vs. C	0.8630	0.74	0.8838	0.78	$n = 0.272C + 0.3189$
4.	Gum karaya	0.1–0.8	312.3–3502.7	0.23–0.32	k vs. C	0.9310	0.87	0.9833	0.97	$k = 163.48e^{3.8C}$
					n vs. C	0.1738	0.03	0.2435	0.06	-
5.	CMC, high viscosity	0.15–1.05	252.9–1298.7	0.30–0.92	k vs. C	0.9485	0.90	0.8631	0.74	$k = 1355.9C - 198.81$
					n vs. C	0.2848	0.08	0.4155	0.17	-
6.	Xanthan gum	0.1–0.7	118.6–7493.8	0.18–0.67	k vs. C	0.9743	0.95	0.8614	0.74	$k = 13134C - 1037.8$
					n vs. C	-0.6589	0.43	0.6669	0.44	$n = 0.1358 \times -0.565C$

Table 4 Correlations between the sensory viscosity rating (SVR) and consistency coefficient (k) of different soluble-fiber dispersions in water

Sr. No.	Fiber preparation	Conc. range (%) [C]	Consistency coefficient (k) mPa.s ⁿ	SVR* range	Linear		Log-Linear		Appropriate regression equation
					R	R ²	R	R ²	
1.	Gum Arabic	3.00–21.00	118.5–193.4	78–98	–0.9754	0.95	0.9674	0.94	SVR = –0.283 k + 132.78
2.	Inulin	2.75–19.25	110.5–398.9	49–100	–0.9359	0.88	0.8971	0.80	SVR = –0.0705 k + 108.86
3.	CMC low viscosity	0.25–1.75	221.4–1288.0	14–99	–0.9346	0.87	0.9365	0.88	SVR = –0.0322 k + 105.22
4.	Psyllium husk	0.15–1.05	250.5–1173.5	21–99	–0.9627	0.93	0.9067	0.82	SVR = –0.0862 k + 124.87
5.	Guar gum	0.07–0.60	61.7–908.7	30–100	–0.7887	0.62	0.5824	0.34	SVR = –0.0765 k + 118.2
6.	Gumtragacanth	0.15–1.20	130.0–1157.2	11–97	–0.9176	0.84	0.9375	0.88	SVR = –0.0897 k + 96.726
7.	Gumkaraya	0.10–0.80	312.3–3502.7	4–97	–0.8555	0.73	0.9940	0.99	SVR = –0.0281 k + 82.394
8.	CMC, high viscosity	0.15–1.05	252.9–1298.7	5–95	–0.9289	0.86	0.8405	0.71	SVR = –0.0684 k + 88.059
9.	Xanthan gum	0.10–0.70	118.6–7493.8	3–89	–0.9855	0.97	0.6914	0.48	SVR = –0.0114 k + 90.258

SVR Sensory viscosity rating

*0 –Extremely high (very difficult to flow); 100 – Extremely low (water-like thin)

Arabic TL-5 was used, for inulin TL-5 and TL-6 were used, for CMC- low-viscosity TL-5 and TL-7 were used, for psyllium husk TL-5 and TL-6 were used, for guar gum LCP, TL-5 and TL-6 were used, for gum Tragacanth TL-5 and TL-7 were used, for gum Karaya TL-5 and TL-7 were used, for CMC-high viscosity TL-5, TL-6 and TL-7 were used and for gum Xanthan TL-5 and TL-7 were used. The apparent viscosity data obtained at different shear rates for each soluble fiber was used to develop instrumental flow behaviour (stress-shear rate flow curve) and regression equations were developed to know the relationship between k (Consistency coefficient), n (Flow-behaviour index), SVR (Sensory Viscosity Rating) and c (concentration).

Results and discussion

Sensory and rheological assessment of soluble fibers

Soluble fibers mainly the gums are known to impart viscosity to the aqueous solutions. Sensory viscosity rating (SVR) of soluble fibers dispersed in water at relatively high concentrations can be seen in Table 1, a higher value of SVR indicating lower viscosity. Psyllium husk (1.00–1.50 %), xanthan gum (1.00–1.25 %), gum karaya (1.00–1.25 %), guar gum (1.50–2.00 %), high-viscosity CMC (1.00–1.50 %) and CMC-low viscosity (1.50–2.00 %) yielded highly viscous solutions or non-flowable gels. On the other hand, low-viscosity fibers viz., gum acacia (10.0–20.0 %) and inulin (15–20 %) were reasonably fluid dispersions. Inulin (25 %) in water tended to gel. The upper concentration limit was worked out from the SVR and the suitable range of concentrations to study flow-curve behaviour was found to be 3–21 % for gum Arabic, 2.75–19.25 % for inulin, 0.25–1.75 % for CMC-low viscosity, 0.15–1.05 % for psyllium husk (powdered), 0.07–0.6 % for guar gum, 0.15–1.2 % for gum tragacanth, 0.1–0.8 % for gum karaya, 0.15–1.05 % for CMC (high viscosity) and 0.1–0.7 % for xanthan gum. In order to characterize the soluble gums with respect to their flow behaviour as a function of concentration, apparent viscosity was determined over the selected range of concentrations and flow-curve (shear stress-shear rate relationship) obtained.

All the fibers in the low- and medium-viscosity category exhibited a ‘power-law’ relationship between the shear stress and shear rate i.e. with an increasing shear rate, the shear stress increased but at a decreasing rate (Figs. 1, 2a and b). This relationship could be expressed as follows:

$$\sigma = k.\dot{\gamma}^n$$

where

- σ Shear stress (mPa)
 k Consistency coefficient (mPa.sⁿ)
 $\dot{\gamma}$ Shear rate (1/s)
 n Flow-behaviour index

Here k is a measure of apparent viscosity and n is a measure of non-linearity of the shear stress-shear rate relationship. Higher the value of k , the greater is viscosity whereas the lower the value of n , the greater the non-linearity (abnormality). Polysaccharide solutions are known to show such a non-Newtonian or shear-thinning behaviour which is primarily interpreted as a progressive mechanical disentangling of molecule chains after initial entanglement, as shear rate increases (Launay et al. 1986). The shear thinning phenomena reflects decreasing viscosity with increasing shear rate. Szczesniak and Farkas (1962) reported that the viscosity of pectin, CMC and sodium alginate declined with increasing shear rate, initially slowly and later rapidly, whereas that of guar gum, tragacanth, carrageenan, gum karaya and psyllium decreased rapidly in the beginning and slowly afterwards.

Table 2 shows the concentration-dependent flow-curve parameters of low- and medium- viscosity soluble fibers. The value of n was smaller for gum acacia (0.14–0.47) and inulin (0.18 at the highest concentration) as compared to that for low-viscosity CMC (0.34–0.60) thereby indicating that CMC showed a smaller non-newtonianness as compared to that of the other two fibers (Table 2). At the lowest concentration, however, inulin solution (2.75 %) exhibited essentially Newtonian flow behaviour. It can be further seen from the table that the consistency coefficient (k) was a function of concentration, the relationship being exponential (R^2 , 0.87–0.96; $P < 0.01$). This is in agreement with the literature reports pertaining to viscosity characteristics of polysaccharide solutions (Launay et al. 1986). The concentration dependence of n was noticed to be high only in case of CMC (R^2 , 0.88 & 0.91) as seen from Table 2.

The flow-curve characteristics of high-viscosity fiber preparations as presented in Table 3 and Fig. 2a and b show that psyllium husk, guar gum, gum tragacanth, gum karaya, high-viscosity CMC and xanthan gum were all shear-thinning in nature as was expected from the earlier scientific findings (Thibault et al. 1992). The consistency coefficient (k) in all fibers and flow behaviour index (n) in all but gum karaya and CMC were directly related to concentration, the relationship largely being exponential (R^2 , 0.61 to 0.98). The relatively smaller value of n for psyllium husk (0.13–0.44) and

gum karaya (0.23–0.32) are indicative of greater non-Newtonianness of these solutions among the high-viscosity fibers.

Relationship between consistency coefficient (k) and sensory viscosity rating (SVR) of soluble-fiber dispersions in water

It can be seen from Table 4 that the lowest values of consistency coefficient (k) for gum Arabic (119–193 mPa.sⁿ) and inulin (111 to 399 mPa.sⁿ) corresponded with relatively higher values of SVR (the score being a direct measure of ‘fluidity’) (49 to 100), the negative correlation being highly significant (−0.98 and −0.94, respectively). In case of other fibers, the relatively high values of k coincided with low values of SVR, the correlation coefficient (−0.79 to −0.99) being significant ($P < 0.01$). Relevant regression equations are presented in Table 4. It may be noticed that the relationship between k and SVR was essentially linear in nearly all cases, the log-linear coefficients of correlation being slightly smaller than the linear ones. The SVR scale ranging from ‘water-like thin’ (rating 100) to ‘too-viscous to flow’ (rating 0) would enable prediction of this sensory attribute from the consistency coefficient using the relevant regression equations developed. Also, the relationship of k with fiber concentration (vide Tables 3 and 4) can identify the concentration of a particular gum required to have the desired consistency in terms of SVR.

Conclusion

The low, medium and high-viscosity fiber preparations of gum Acacia, inulin, CMC-low viscosity, psyllium husk, guar gum, gum tragacanth, gum karaya, CMC high-viscosity and xanthan gum studied in the present study showed that the consistency coefficient (k) and the flow behaviour index (n) were dependent on concentration at a constant shear rate. The SVR could be predicted from k using the developed regression equations. Understanding the critical rheological parameters and their relationship with desired SVR, new product developers can develop healthy fiber-fortified products with acceptable consistency.

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Appendix

Intensity rating of sensory viscosity of hydrocolloid solutions/dispersions in water

Lot No.: _____

Date: _____

Kindly examine the gum samples for their viscosity/consistency and appropriately indicate the rating along the vertical linear scale given below:

Sign. / Name: _____

References

- Allen LH (2013) Dietary fiber: Role in nutritional management of disease. In: Encyclopedia of Human Nutrition 2:55–59. doi:[10.1016/B978-0-12-375083-9.00107-0](https://doi.org/10.1016/B978-0-12-375083-9.00107-0)
- Amiri EO, Nayebezhadeh K, Mohammadifar MA (2015) Comparative studies of xanthan, guar and tragacanth gums on stability and rheological properties of fresh and stored ketchup. J Food Sci Technol 52(11):7123–7132
- Anderson JW, Floore TL, Geil PB, O'Neal DS, Balm TK (1991) Hypocholesterolemic effects of different bulk-forming hydrophilic fibers as adjuncts to dietary therapy in mild to moderate hypercholesterolemia. *Arch Intern Med* 151:1597–1602
- Belitz HD, Grosch W (1999) Food Chemistry. Springer-Verlag, Berlin pp 285–311
- Cevoli C, Balestra F, Ragni L, Fabbri A (2013) Rheological characterization of selected food hydrocolloids by traditional and simplified techniques. Food Hydrocoll 33:142–150
- Chen J (2009) Food oral processing – a review. Food Hydrocoll 23:1–25
- Craig SAS, Holden JF, Troup JP, Auerbach MH, Frier H (1999) Polydextrose as soluble fiber and complex carbohydrate. In: Cho SS, Prosky L, Dreher M (eds) Complex Carbohydrates in Foods. Marcel Dekker Inc., NY, p. 235
- Cui SW, Nie S, Roberts KT (2011) Functional properties of dietary fiber. Canada, Elsevier, B.V., pp. 517–525
- Fiszman S, Varela P (2013) The role of gums in satiety/satiation. A review. Food Hydrocoll 32:147–154
- Kaur S, Shevkani K, Singh N, Sharma P, Kaur S (2015) Effect of guar gum and xanthan gum on pasting and noodle-making properties of potato, corn and mung bean starches. J Food Sci Technol 52(12):8113–8121
- Launay B, Doublier JL, Cuvelier G (1986) Flow properties of aqueous solutions and dispersions of polysaccharides. In: Mitchell JR, Dedward DA (eds) Functional properties of Food Macromolecules. Elsevier Applied Sci. Publ, London, pp. 1–76p
- Marcotte M, Taherian HRA, Ramaswamy SH (2001) Rheological properties of selected hydrocolloids as a function of concentration and temperature. Food Res Intl 34:695–703
- Moskowitz HR (1972) Scales of subjective viscosity and fluidity of gum solutions. J Texture Stud 3:89–100
- Mudgil D, Barak S, Khatkar BS (2014) Guar gum: Processing, properties and food applications- a review. J Food Sci Technol 51(3):409–418
- Oakenfull D (2001) Physicochemical properties of dietary fiber: Overview. In: Cho SS, Dreher ML (eds) Handbook of dietary fiber. Marcel Dekker, Inc. New York, 197p
- Phillips, G.O. and Williams, P.A. (2009) Handbook of Hydrocolloids. 2nd edn. Cambridge, Woodhead Publishing limited.
- Roberfroid MB (1999) Dietary fiber properties with health benefits of non-digestible oligosaccharides. In: Cho SS, Prosky L, Dreher M (eds) complex Carbohydrates in Foods. Marcel Dekker, Inc, New York, pp. 25–27p
- Szczesniak AS, Farkas E (1962) Objective characterization of the mouth-feel of gum solutions. J Food Sci 27:381–385
- Thibault JF, Lahaye M, Guillon F (1992) Physico-chemical properties of food plant cell walls. In: Schweizer TF, Edwards CA (eds) Dietary fiber – A Component of Food. ILSI Human Nutrition Reviews. Springer-Verlag, London, pp. 21–39
- Topping DL (2013) Dietary fiber: Physiological effects and health outcomes. In: Encyclopedia of Human Nutrition 2:50–54. doi:[10.1016/B978-0-12-375083-9.00106-9](https://doi.org/10.1016/B978-0-12-375083-9.00106-9)
- Waldt LM (1961) Technology of natural gums and stabilizers. Food Process 22(4):122
- Werbin SJ (1953) Vegetable gums, their properties and uses. Baker's Digest 27(4):71