Development of protein fortified mango based ready-to-serve beverage

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Abstract Fruit drinks contain negligible amount of protein as nutritional component. Fortification of fruit drinks with protein is a challenge due to protein stability in acidic and ionic environment. Mango ready-to-serve (RTS) beverage was fortified with modified whey protein and its rheological properties were studied. Whey protein was hydrolysed with papain to improve its stability in acidic medium. The water holding capacity of whey protein increased about two times after hydrolysis. Hydrolysed and native whey protein was used at 2, 3 and 4% levels for fortification of mango based RTS beverage. Addition of hydrolysed whey protein at all the three levels did not significantly change the flow behaviour of the beverage. Native whey protein fortification resulted in precipitation; however, addition of hydrolysed whey protein led to stable beverage formulation at all the three levels. Hydrolysed whey protein imparted slight bitter taste to the RTS beverage, which was masked by β -cyclodextrin @ 0.15% of total protein. The mango RTS beverage with 3.0% hydrolysed whey protein was found acceptable with good sensory appeal and stability during thermal processing as well storage in glass bottles.

Keywords Hydrolysed whey protein · Fortification · RTS beverage · Steady state rheology

Introduction

Fruit juices provide basic micro-nutrients like vitamins, minerals and antioxidants in addition to its refreshing and thirst quenching ability. Further, fruit based drinks are generally formulated for their carbohydrate and mineral content to meet the specific need. Almost all the fruits/fruit drinks lack the protein as a nutritional component. Protein helps in faster recovery of the muscles following severe exercise. Role of protein in the energy drink is well established and is believed to be superior to glucose (Segall 2009). Stabilization of the protein in the acidic and ionic environment of fruit drink is the major challenge. Most of the fruit drinks had pH range of 3.0–4.0, whereas most of the food proteins precipitate in this pH range. Further, the fruit drinks are thermally processed to preserve and to comply the prevailing food standards. The thermal impact in this pH range destabilizes the protein in the food system (Ryan et al. 2012) and thus affects the rheology of the dispersion. The protein hydrolysates (limited hydrolysis) can be an excellent ingredient to fortify the foods owing to advantages like greater and instant solubility, easily digestible form and stability over wide range of pH. Bitterness of the protein hydrolysates is the limiting factor for the food applications. Whey proteins are generally preferred for the food fortifications because of its high (100%) protein-digestibility-corrected amino acid score (Sizer and Whitney 1994). Attempts have been made to develop the whey protein fortified fruit beverages in the past. Sharma et al. (1998) fortified orange juice with 4% native whey proteins and reported higher apparent viscosity as well as

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sedimentation during storage in the heat treated samples. Rittmanic (2006) reported that un-modified whey proteins may not be stable as the sole protein ingredient at levels above 3% and gets precipitated under acidic conditions unless a stabilizing system is used. Lee and Vickers (2008) observed the astringency of acidic whey protein beverages caused by their high acidity rather than by the whey proteins directly. Ryan et al. (2012) also observed that whey protein beverage suffer from precipitation due to aggregation of thermally denatured proteins. Goudarzi et al. (2015) reported higher clarity of apple juice beverage fortified with WPH as compared to beverage fortified with WPI at pH values closer to the iso-electric pH of the whey proteins.

Rheological parameters such as viscosity and flow behaviour are the key properties of any beverage, which determines the processing requirement as well as quality and acceptability of the product. Mango RTS beverage is the most common fruit drink available in the Indian market due to its wide popularity and high mango production (17.29 mT in 2012–2013, DoAC 2015). Therefore, the present study was conducted with an objective to develop the mango RTS beverage fortified with whey protein and to evaluate its impact on rheological behaviour of the beverage.

Materials and methods

Ripe mangoes (*var. Banganapalli*) were procured from the local market of Ludhiana, Punjab, India. The fruits were washed with water and surface water was removed before peeling. The pulp was extracted using food processor (M/s Inalsa Maxie Plus, New Delhi, India) and stored in refrigerator (4 °C) for further use. Whey protein concentrate (WPC-80, 80% protein) was procured from M/s Mahaan Proteins Ltd., New Delhi, India. Purified papain was procured from M/s SD Fine Chemicals Ltd., Mumbai, India. All other requisite chemicals used in the study were procured from M/s Hi-media laboratories Mumbai, India.

Preparation of whey protein hydrolysates

Hydrolysis of WPC was carried out as described by Silvestre et al. (2012) with minor modifications. The WPC was dissolved in distilled water to make 12.5% (w/v) solution and pH was adjusted to 6.5 using 2% citric acid solution for optimum papain activity. The solution was allowed to hydrate at 30 °C for 2 h. Thereafter, the temperature of the solution was increased to 50 °C. Papain enzyme (0.75%, w/w of protein, pre-trial basis) was added and the solution was stirred continuously at 50 °C for 2 h (pre-trial basis). The pH was maintained at 6.5 using 1 N

NaOH solution during hydrolysis process. At the end of 2 h, the solution was heated at 100 °C for 5 min in order to inactivate the enzyme activity. Hydrolysed protein solution was spray dried (inlet air temperature: 180 °C, outlet air temperature: 90 °C, blower speed: 2500 rpm and feed rate: 800 mL/h) using table top spray dryer (M/s SM Scientech, Kolkata, India). The dried whey protein hydrolysate (WPH) was packed in airtight containers and stored at 4 °C for further use.

Degree of hydrolysis

Degree of hydrolysis (DH) is defined as the percentage of free amino groups cleaved from protein, which was calculated as ratio of α -amino nitrogen and total nitrogen. The α -amino nitrogen was determined by titration method (USP 1989). Ten ml of above WPH solution was mixed with an equal amount of distilled water and pH of the solution was adjusted to 7.0 using 0.1 N NaOH. Then 10 ml of formaldehyde solution (38%, v/v) was added and titrated against 0.2 N standard NaOH solution. Total nitrogen was determined by Kjeldhal method (AOAC 1990).

Protein solubility index (PSI)

PSI of WPC and WPH was determined by the method described by Chobert et al. (1988). Protein solution (100 ml of 5% concentration) was stirred at 300 rpm for 1 h at 25 °C and centrifuged at same temperature for 30 min at 8000 rpm. PSI was calculated as the ratio of protein content of supernatant and total protein content of the sample.

Water holding capacity (WHC)

WHC was determined using the method outlined by Beuchat (1977). Whey protein (1.0 g) was dissolved in 10 ml of distilled water. The content was mixed using vortex for 5 min and allowed to stand for 30 min at 30 °C. Samples were centrifuged in pre-weighed tubes at 8000 rpm for 20 min at 30 °C. The supernatant was decanted and the centrifuge tube containing pellet was weighed. WHC was calculated as the ratio of the pellet weight and weight of sample. The results were expressed as g water/g of protein.

Preparation of mango RTS beverage

RTS beverage was prepared using mango pulp, refined sugar, WPC/WPH as per the formulations given in Table 1. 170.0 g of mango pulp, 130.0 g sugar and appropriate amount (2, 4 and 6%) of WHC/WPH were mixed with 150 ml of distilled water. After mixing, pH of the each sample was adjusted to 3.0 using 5.0% citric acid solution.

Table 1 Formulation used in preparation of protein fortified mango RTS beverage

Sample	Mango pulp (% w/w)	Sugar (% w/w)	WPC/WPH (% w/w)
Control	17	13	0
WPC-2/WPH-2	17	13	2
WPC-3/WPH-3	17	13	3
WPC-4/WPH-4	17	13	4

WPC whey protein concentrate, WPH hydrolysed whey protein

0.15% β -cyclodextrin (total protein basis, w/w) was also added in order to mask bitterness imparted by the whey protein. The final volume (1.0 l) was made up using distilled water. The samples (180.0 ml) were filled in pre-sterilized glass bottles (200 ml) and pasteurized at 85 °C for 15 min in water bath thereafter, immediately cooled to 10 °C in chilled water bath. The pasteurized samples were stored at 4–6 °C in refrigerator.

Steady state rheology

Rheological properties (apparent viscosity, flow behaviour index and consistency index) of the WPC and WPH fortified RTS beverages were measured in triplicate using a rheometer (MCR 101, Anton Paar, GmbH, Ostfildern, Germany). The measurements were carried out using a concentric cylinder arrangement (DG 26.7-SN7721). A thin layer of low-density oil was spread on top of the samples to minimize moisture loss. Shear rate was increased linearly from 0.1 to 100 s⁻¹ to generate shear stress and apparent viscosity data. The mixture was pre-sheared for 5 s at a constant shear rate of 100 s⁻¹ at 20 °C and held for 30 s to equilibrate before data collection. All measurements were performed at 20 °C. The samples were allowed to rest for 5 min in the sample cell for temperature equilibration (Sopade et al. 2007). In order to study the flow behaviour of unpasteurized samples, temperature sweep test was also performed. The samples were heated from 10 to 90 °C @ 10 °C/min at constant shear rate (100 s⁻¹). The data was acquired in a personnel computer loaded with Rheoplus (v2.81, Anton Paar) software.

Mathematical modelling of steady state rheology

The mango RTS beverage exhibited yield stress at selected temperatures. Therefore, the models incorporating yield stress term were selected for describing steady state relationships between shear rate and shear stress. The selected models were Casson, Heinz–Casson, Herschel–Bulkley (HB), Mizrahi–Berk and Vocadlo models (Eqs. 1–5).

$$\text{Casson} \quad \tau = \left(\tau_o^{1/2} + K\gamma^{1/2} \right)^2 \quad (1)$$

$$\text{Heinz–Casson} \quad \tau = (\tau_o + K\gamma^n)^{1/n} \quad (2)$$

$$\text{Herschel–Bulkley} \quad \tau = \tau_o + K\gamma^n \quad (3)$$

$$\text{Mizrahi–Berk} \quad \tau = \left(\tau_o^{1/2} + K\gamma^n \right)^2 \quad (4)$$

$$\text{Vocadlo} \quad \tau = \left(\tau_o^{1/n} + K\gamma \right)^n \quad (5)$$

where τ is shear stress (Pa); τ_o is yield stress (Pa); K (sⁿ) is consistency index; γ is shear rate (s⁻¹); and n is the parameters of models related to the flow behavior index (dimensionless) signifying the extent of deviation from Newtonian behavior.

Dependence of flow behavior index (n) of selected models on the concentration of WPC/WPH was described by the second order relationship.

Sensory evaluation

The samples were evaluated for sensory attributes (consistency, taste, bitterness, flavour and overall acceptability) by a semi-trained panel consisting of 10 scientific staff members of the laboratory with knowledge of consumer's preference using a nine-point hedonic scale having a score of 9 for extreme liking and 1 for extreme disliking (Larmond 1977).

Storage study

The pasteurised samples were stored at 4 °C for 90 days in glass bottles and analysed for pH, microbial count and sensory acceptability during the period at an interval of 30 days.

Microbiological analysis

Microbial analysis of pasteurized samples was carried out according to the method described by Harrigan and McCance (1976). Total plate count, coliforms, yeast and mould were enumerated in the samples. The average number of colony forming units (cfu/g) from the duplicate plate of the same dilution were counted, multiplied with the dilution factor and expressed as cfu $\times$ 10ⁿ/g of sample (n = dilution factor).

Statistical analysis

All the measurements were replicated thrice and average values were used. The shear rate–shear stress data were fitted to selected models for the temperature range under

study. The non-linear least square regression analysis was done using Statistica version-6 software to compute the regression coefficients of the models. The quantitative error parameters and pattern of residual plots were used to ascertain the ability of the models to describe rheological behaviour of the samples.

The standard error of estimate (SEE) and mean relative deviation modulus (MRD) were used as statistical parameters to predict the fitting ability of models. The SEE represents the deviation of the dependent variable τ_i ,

$$SEE = \sqrt{\frac{\sum_{i=1}^n (\tau_i - \tau_p)^2}{d_f}} \quad (6)$$

$$MRD = \frac{100}{n} \sum_{i=1}^n \frac{|\tau_i - \tau_p|}{\tau_i} \quad (7)$$

where τ_i is observed value of shear stress (Pa); τ_p is predicted value of shear stress (Pa); d_f is degree of freedom; and n is sample population.

Results and discussion

Solubility and water holding capacity of native and hydrolysed whey protein

The solubility and water holding capacity (WHC) are unique property of any protein, which allows their application in beverage formulations. The degree of hydrolysis (DH) of hydrolysed whey protein (WPH) was $9.2 \pm 0.21\%$. The solubility of WPH was observed significantly ($P < 0.05$) higher ($90.8 \pm 0.62\%$) than native WPC (83.7 ± 0.55). The WHC also increased to 6.7 from 3.1 g water/g of protein after hydrolysis. The increase in solubility after hydrolysis may be result of liberation of low molecular weight peptides and increase in number of ionizable groups (NH_4^+ , COO^-), which leads to increase in hydrophilicity and net charge, thus enhancing solubility by promoting interactions between hydrolysate and water (Jeewanthi et al. 2015). The increase in WHC of WPH is the result of exposure of unexposed hydrophobic amino acids and their interactions with surface hydrophobic amino acids or similar peptides. This allows the formation of new aggregates to hold water (Kneifel and Seiler 1993). Another reason may be due to unfolding of protein structure during hydrolysis as well as heat treatment, which allows more interactions of polar amino acids with water. Papain enzyme cleaves the peptide bond at Arg and Lys with preceding hydrophobic amino acid residue.

Apparent viscosity profile

Apparent viscosity profile (before and after pasteurization) of mango RTS beverages fortified with WPC and WPH at various levels are shown in Fig. 1. Both beverages exhibited shear thinning behaviour irrespective of type of proteins and its level. According to Graessley (1974) the interpenetration of polymer chains in concentrated solutions gives rise to a dynamic entangled network. With increasing shear rate, the cross-link density of the network is depleted and viscosity reduced.

Apparent viscosities (μ) of WPC fortified beverage increased significantly ($P < 0.05$) with increase in the level of WPC (Fig. 1a) at respective shear rates. It can be depicted from the figure that μ of the beverage with WPC

Fig. 1 Changes in apparent viscosity of pasteurized (P) and un-pasteurized (UnP) mango RTS beverages fortified with different levels (2, 3 and 4%) of: **a** WPC and **b** WPH with respect to shear rate

was significantly ($P < 0.05$) reduced after pasteurization at all levels as compared to unpasteurized samples. Protein molecules present in the beverage might be denatured during the pasteurisation which attributed to the reduction in apparent viscosity. Further, the μ of WPC fortified beverage were observed significantly ($P < 0.05$) higher than control in both the samples i.e. un-pasteurized and pasteurized. It may therefore be inferred that the addition of WPC may act as thickener in mango RTS beverage.

In WPH fortified beverage, the μ did not differ significantly at all the levels of fortification (Fig. 1b) with respect to shear rates in unpasteurized samples. It can also be noted from the Fig. 1b that the μ of the samples did not change significantly even after pasteurisation. This may be due to increased solubility of WPH (Flanagan and Fitzgerald 2002; Jeewanthi et al. 2014). Limited hydrolysis leads to increased solubility due to the reduced molecular weight and the increased hydrophilicity resulting from the increase in free carboxyl and amine groups (Jeewanthi et al. 2015). Foegeding et al. (2002) also reported that heat stability of proteins can be improved upon partial hydrolysis due to loss of secondary structure and thus contributing to reduced structural changes upon heating. Moreover, preparation of WPH involves hydrolysis followed by spray drying (180 °C). Drying at high temperature might have denatured the protein and hence did not alter the μ of beverage. The μ of WPH fortified RTS samples were significantly ($P < 0.05$) lower than WPC fortified samples (Fig. 1). It may therefore be inferred that the addition of WPH up to 4% may not alter the flow behaviour of RTS beverage.

To ascertain the effect of temperature on μ of the RTS samples, temperature sweep test was conducted and

variation of μ with temperature is shown in Fig. 2. It was observed that the μ of control sample decreased up to 66 °C and thereafter increased. However, the μ of whey protein fortified samples decreased continuously with increase in temperature. The increase in μ of control sample after 66 °C may be due to the absorption of water molecules by pectic substances, gums and sugars present in the sample. Whereas, continuous decrease in the μ of whey protein fortified samples may be due to the formation of protective layer over the pectic substances, gums and sugars molecules and thus did not allow absorption of water by these molecules. Therefore, it may be inferred that the WPC and WPH fortified (up to 4% level) RTS beverage may flow easily at higher temperatures.

Steady state rheology

The experimental steady shear flow curves obtained at 20 °C for WPC and WPH fortified RTS beverages at different levels after pasteurisation are shown in Fig. 3. The results indicated that differences in shear stress values at selected concentrations of WPC fortified RTS samples were significantly ($P < 0.05$) higher than those of WPH fortified samples. Selected mathematical models were tested to evaluate the rheological behaviour of both the samples.

Models that include yield stress terms are more adequate to describe rheological behaviour of polysaccharides exhibiting yield stress (Marcotte et al. 2001; Hosseini-Parvar et al. 2010). Computed values of the parameters (K , n , R^2 , SEE, and MRD) and pattern of residual plot of the models evaluated at selected concentrations of WPC and

Fig. 2 Variations in apparent viscosity of un-pasteurized (UnP) mango RTS beverages fortified with different levels (2, 3 and 4%) of WPC/WPH during temperature sweep test

Fig. 3 Shear rate-shear stress relationship of pasteurized (P) RTS beverages fortified with different levels (2, 3 and 4%) of WPC and WPH

WPH for un-pasteurized and pasteurized samples are presented in Tables 2 and 3, respectively. Based on R^2 , SEE, MRD values and scattered residual plot, the Mizrahi-Berk and Hershel-Bulkley models adequately described the rheological behaviour of the fortified RTS samples. Residual plot of Mizrahi-Berk model was scattered with less deviation from the observed values indicating that the prediction by this model was most satisfactory.

Dependence of flow behaviour on concentration

Variations in consistency index (K) values obtained by Mizrahi-Berk model were not consistent with concentration for WPC fortified samples, whereas, it consistently increased for WPH fortified samples. Further, the flow behaviour index (n) increased abruptly at 4% level of WPC, indicating that the protein particles may be in suspended form in the sample. However, it was almost constant and was less than one for WPH fortified samples thus indicating shear thinning behaviour. It may therefore be inferred that fortification of RTS with WPH may not alter the flow behaviour. Dependence of n on concentration of WPC and WPH can be described by the following relationships.

$$\text{WPC - UnP: } n = 0.10C^2 - 0.23C + 0.34 \quad (R^2 : 0.95) \quad (8)$$

$$\text{WPC - P: } n = 0.05C^2 - 0.05C + 0.34 \quad (R^2 : 0.68) \quad (9)$$

$$\text{WPH - UnP: } n = -0.01C^2 + 0.04C + 0.30 \quad (R^2 : 0.99) \quad (10)$$

$$\text{WPH - P: } n = -0.01C^2 + 0.08C + 0.30 \quad (R^2 : 0.99) \quad (11)$$

where WPC-UnP is native whey protein fortified unpasteurized sample; WPC-P, native whey protein fortified pasteurized sample; WPH-UnP, hydrolysed whey protein fortified unpasteurized sample; WPH-P, hydrolysed whey protein fortified pasteurized sample. *Sensory and storage stability.*

Initially, all the samples (except the sample, which contain 4% WPH) were acceptable and scored more than 8 for overall acceptability score. However, sedimentation was observed in RTS beverages fortified with WPC at all levels after 24 h of storage, which may be due to loss of solubility during pasteurization. Stoliar (2009) also reported that heating of whey proteins can result in loss of solubility due to the denaturation of proteins in acidic pH. Whereas, this problem was not observed in RTS beverages fortified with WPH throughout the storage period. This may be due to increase in solubility of hydrolysates with less secondary structure and low molecular weight fractions. However, the samples with 4% WPH had slight bitter taste as noticed by the panellists and scored lower score (<7.0) for overall acceptability. Microbiological analysis of the samples showed that all the samples were free from TPC, coliforms, yeast and mould even after 90 days of storage. There was no significant change in the pH of the

Table 2 Estimation of the parameters and goodness of fit for the selected rheological models for mango RTS beverage prior to pasteurization

Model	Sample	Parameters						
		τ_o (Pa)	K (Pa.s ⁿ)	n	R ²	SEE	MRD	Residual plot
Casson	Control	0.53	0.03	–	0.98	0.02	1.28	Patterned
	WPC-2	0.74	0.08	–	0.99	0.08	2.05	Patterned
	WPC-3	1.45	0.10	–	0.99	0.03	0.66	Patterned
	WPC-4	7.64	0.06	–	0.96	0.21	1.72	Patterned
	WPH-2	0.34	0.07	–	0.99	0.03	2.55	Patterned
	WPH-3	0.33	0.08	–	0.99	0.03	2.43	Patterned
	WPH-4	0.27	0.08	–	0.99	0.03	2.81	Patterned
	Heinz–Casson	Control	0.77	0.06	0.30	0.99	0.01	1.19
WPC-2		0.76	0.16	0.27	0.99	0.01	0.55	Patterned
WPC-3		1.08	0.13	0.41	0.99	0.02	0.45	Patterned
WPC-4		10.81	0.03	1.11	0.99	0.07	0.61	Patterned
WPH-2		0.59	0.17	0.26	0.99	0.02	1.03	Scattered
WPH-3		0.57	0.19	0.24	0.99	0.01	0.47	Scattered
WPH-4		0.53	0.21	0.22	0.99	0.01	0.78	Scattered
Hershel Bulkley		Control	0.45	0.08	0.41	0.99	0.01	1.22
	WPC-2	0.54	0.21	0.51	0.99	0.01	0.44	Scattered
	WPC-3	1.39	0.24	0.58	0.99	0.02	0.50	Scattered
	WPC-4	8.61	0.02	1.09	0.99	0.07	0.61	Scattered
	WPH-2	0.23	0.12	0.55	0.99	0.02	1.05	Scattered
	WPH-3	0.22	0.13	0.56	0.99	0.01	0.69	Scattered
	WPH-4	0.16	0.11	0.56	0.99	0.01	0.97	Scattered
	Mizrahi–Berk	Control	0.43	0.07	0.33	0.99	0.01	1.20
WPC-2		0.42	0.21	0.34	0.99	0.01	0.51	Scattered
WPC-3		1.25	0.15	0.43	0.99	0.02	0.45	Scattered
WPC-4		8.59	0.01	1.03	0.99	0.07	0.62	Scattered
WPH-2		0.17	0.17	0.35	0.99	0.02	1.01	Scattered
WPH-3		0.15	0.19	0.35	0.99	0.01	0.54	Scattered
WPH-4		0.10	0.19	0.35	0.99	0.01	0.85	Scattered
Vocadlo		Control	0.53	0.01	0.21	0.98	0.01	1.43
	WPC-2	0.71	0.12	0.41	0.99	0.01	0.43	Scattered
	WPC-3	1.62	0.38	0.42	0.99	0.03	0.75	Patterned
	WPC-4	8.58	0.01	2.61	0.99	0.08	0.62	Patterned
	WPH-2	0.32	0.03	0.46	0.99	0.02	1.26	Scattered
	WPH-3	0.30	0.03	0.49	0.99	0.01	1.03	Patterned
	WPH-4	0.23	0.03	0.50	0.99	0.01	1.19	Patterned

WPC whey protein concentrate, WPH hydrolysed whey protein, SSE standard error of estimate, MRD mean relative deviation modulus, K consistency index, τ_o yield stress

samples and lies between 3.0 and 3.12 throughout the storage period.

Conclusion

Native whey proteins are heat sensitive and get denatured during pasteurization/thermal processing. Therefore, RTS fruit beverages fortified with native whey proteins may suffer from the problem of sedimentation during storage

which adversely affects its consumer acceptability. However, partial hydrolysis of whey proteins results in higher solubility and heat stability even at acidic pH. Present study showed that partially hydrolyzed whey protein (DH 9.2%) can be used at 3% level for the fortification of mango based RTS beverage (pH 3.0) without any sedimentation and with good sensory acceptability. Since, protein fortified fruit juices/drinks are not available in the Indian market. Therefore, the whey protein (partially hydrolyzed) fortification of fruit juices may provide an

Table 3 Estimation of the parameters and goodness of fit for the selected rheological models for mango RTS beverage after pasteurization

Model	Sample type	Parameters						
		τ_o (Pa)	K (Pa.s ⁿ)	n	R ²	SEE	MRD	Residual plot
Casson	Control	0.45	0.03	–	0.98	0.02	1.44	Patterned
	WPC-2	0.60	0.08	–	0.99	0.04	1.69	Patterned
	WPC-3	0.99	0.11	–	0.99	0.04	1.35	Patterned
	WPC-4	4.70	0.11	–	0.96	0.32	3.19	Patterned
	WPH-2	0.27	0.08	–	0.99	0.02	1.67	Patterned
	WPH-3	0.25	0.10	–	0.99	0.02	1.69	Patterned
	WPH-4	0.23	0.09	–	0.99	0.02	1.88	Patterned
Heinz–Casson	Control	0.73	0.07	0.27	0.99	0.01	0.99	Scattered
	WPC-2	0.84	0.04	0.71	0.99	0.02	1.24	Patterned
	WPC-3	0.87	0.16	0.35	0.99	0.02	0.49	Scattered
	WPC-4	9.44	0.04	1.23	0.99	0.04	0.38	Patterned
	WPH-2	0.52	0.16	0.33	0.99	0.01	0.46	Scattered
	WPH-3	0.49	0.17	0.33	0.99	0.02	0.95	Scattered
	WPH-4	0.47	0.18	0.31	0.99	0.01	0.54	Scattered
Herschel Bulkley	Control	0.35	0.09	0.40	0.99	0.01	1.03	Scattered
	WPC-2	0.80	0.04	0.80	0.99	0.02	1.08	Scattered
	WPC-3	0.87	0.23	0.58	0.99	0.01	0.34	Scattered
	WPC-4	6.21	0.02	1.17	0.99	0.04	0.38	Scattered
	WPH-2	0.23	0.08	0.64	0.99	0.01	0.67	Scattered
	WPH-3	0.22	0.09	0.66	0.99	0.02	1.07	Scattered
	WPH-4	0.19	0.09	0.67	0.99	0.01	0.82	Scattered
Mizrahi–Berk	Control	0.33	0.09	0.31	0.99	0.01	1.00	Scattered
	WPC-2	0.75	0.04	0.62	0.99	0.03	1.34	Scattered
	WPC-3	0.72	0.19	0.40	0.99	0.02	0.45	Scattered
	WPC-4	6.16	0.01	1.04	0.99	0.04	0.39	Scattered
	WPH-2	0.16	0.15	0.41	0.99	0.01	0.51	Scattered
	WPH-3	0.15	0.16	0.42	0.99	0.02	0.94	Scattered
	WPH-4	0.12	0.16	0.41	0.99	0.01	0.60	Scattered
Vocadlo	Control	0.43	0.01	0.23	0.99	0.01	1.30	Scattered
	WPC-2	0.84	0.04	0.64	0.99	0.02	0.82	Scattered
	WPC-3	1.07	0.21	0.47	0.99	0.02	0.44	Patterned
	WPC-4	6.13	0.01	2.82	0.99	0.04	0.41	Patterned
	WPH-2	0.29	0.03	0.56	0.99	0.01	0.97	Scattered
	WPH-3	0.28	0.03	0.61	0.99	0.02	1.28	Scattered
	WPH-4	0.25	0.03	0.61	0.99	0.01	1.15	Scattered

WPC whey protein concentrate, WPH hydrolysed whey protein, SEE standard error of estimate, MRD mean relative deviation modulus, K consistency index, τ_o yield stress

opportunity for Indian industries to introduce protein fortified fruit drinks in India.

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