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Short communication

Influence of particle size on rheological properties of mango peel powder

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ABSTRACT

This study was envisaged to investigate the effect of particle size on the rheological characteristics of mango cv. Bangalora peel powder under ambient conditions using a rotational rheometer. The consequences of sample concentration, *i.e.*, powder: water (1:4, 1:5, 1:6) was also evaluated. Sieve analysis using screens (420, 355, 250, 125 microns) was done to achieve the desired variation in particle size. Shear stress-shear rate data was adequately fitted to Herschel-Bulkey, Power law and Casson law and the rheological properties were represented graphically by rheograms for 0 to 100 s^{-1} shear rate. Relative parameters and regression analysis against each model determined the flow characteristics of the samples. Selected three models showed well representation of the rheological data, with high regression coefficients. Model parameters (consistency coefficient, flow behaviour index and R^2) validated the deviation in rheological characteristics with particle size and sample concentration. Shear stress (τ) increases steeply with sample concentration for equivalent particle size, however, for the same sample concentration, negative correlation of particle size with shear stress was reported. The identification of suitable particle size and sample concentration might be useful in understanding of rheological properties of the peel powder of selected cultivar.

Key words: Mango, particle size, peel powder, rheological properties.

Mango (*Mangifera indica* L.) occupies prominent position in the world market, being among the main fruits of immense commercial importance. Mango peel which constitutes about 15-20% of the fruit (Beerh *et al*., 5) is rich in dietary fibre, pectin, carotenoids, polyphenols, antioxidants and enzymes (Ajila *et al*., 3; Kim *et al*., 9; Koubala *et al*., 10). To explore the possibility of using mango peel in food processing operations, it becomes quite neccesary to understand its rheological properties with respect to particle size. The rheological behaviour of any material may vary as a function of concentration, temperature, particle size, concentration of solute, molecular weight, pressure, suspended matter, processing conditions and the addition of additives *etc*. (Bourne, 6; Kumar *et al*., 11). Flow behaviour of liquid food samples can be very well described using different rheological models (Power law, Casson law and Power law with yield stress (Herschel-Bulkley) depending upon its characteristics (Vandresan *et al*., 16). Despite of its importance for food quality, any systematic study does not correlates with the relationship of particle size distribution and rheology of fruit peel powder suspensions. Hence, this study was envisaged to investigate the effect of particle size and sample concentration on the rheological properties of mango cv. Bangalora peel powder.

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Fresh and fully ripened fruits of mango cv. Bangalora were obtained from the orchard of Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu. Fruits were manually peeled with a knife and further peels were washed to remove the pulp and dirt substance adhered. Thereafter, peels were subjected to drying using solar dryer initially (maximum temperature: 40 ± 2°C with 70% RH) to remove significant amount of moisture. Further, these samples were kept in tray dryer (50 ± 3°C for 12 h) until the final moisture content reaches 12-14% (w.b.). Later on, dried peel was grounded into fine powder using laboratory grinder (Phillips India, 750 W).

During powder making of peel, particles having broad variation in size, shape and surface characteristics were formed. Therefore, it becomes quite difficult for better understanding of the rationale behind variation in rheological properties as a function of particle size. Sieve analysis was performed to obtain a uniform size range of particles which helped in demonstrating the particle size dependency on the rheological properties. The powder was sieved using sieve shaker and separated into four different fractions 420 μ (A), 355 μ (B), 250 μ (C) and 125 μ (D). Samples were collected and packed in zip lock covers, wrapped in aluminium foil and kept in refrigerator at 4-6°C. The required sample amount was taken as per the need. Further, for better understanding of viscosity related properties, test samples with 1:4, 1:5 and 1:6 concentration (powder: water) were prepared in triplicate and subjected for evaluation on rheometer. The moisture content of fresh as well as dried peels was determined using hot air-oven method (130 ± 5°C for 1 h) until it reaches to constant weight. Peel powder (1 g) was mixed with water to make the ratio of powder: water as 1:3, 1:4, 1:5, 1:6, 1:7 and 1:8 and checked for flowability and consistency. Samples (1:4, 1:5 and 1:6) were observed to contain desired flow characteristics, hence, selected for further experimentation in order to evaluate their rheological behaviour.

Rheological measurements were made *via* Rheometer make Antonpaar, model Rheoplus /32 MCR 52 (Probe: PP50, Diameter 49.984 mm, Part No. 79045) parallel plates with the measuring system PP50-SN26252 and measuring cell P-PTD 200/ AIR- SN80967699. All the measurements were taken at 33 ± 1°C. A sample of approximately 10 ml was placed in the sample space of rheometer for measurement. Usually, Power Law is used to indicate pseudoplasticity due to dissolved solids, through the fluid behaviour index *n* (Pelegrine *et al*., 14). The shearing rheological behaviour of a fluid is represented by a straight line in power law (Keshani *et al*., 8). It can be described as τ = Kγn. Where τ is the shear stress (Pa); γ the shear rate (s^{-1}); K the consistency coefficient (Pa s^n) and *n* the flow behaviour index of product. Two more parameters ('a' and 'b') associated with Power law model analysis were referred to be as regression parameters. Casson proposed the (τ)^0.5 = (τoc)^0.5 + Kc (γ)^0.5 following expression which was used to demonstrate the effect of suspended material (Pelegrine *et al*., 14). Herschel-Bulkley expressed τ = τo + Kγ^n equation. τ_o and τ_{oc} are yield stress (Pa) and Casson yield ($Pa^{0.5}$) respectively, γ is shear rate (s^{-1}), K is the consistency coefficient (Pa s^n), Kc is Casson constant $(Pa\ s)^{0.5}$ and n is flow behaviour index (dimensionless).

The models, *viz.*, Herschel-Bulkley, Power and Casson laws were used as a tool for estimation of the relationship between shear stress and shear rate. The estimated values of the model parameters helped in characterisation of the flow behaviour of tested samples. The data obtained during rheological examination was subjected to model analysis and regression coefficients were recorded and compared. Various other parameters like flow behaviour index, consistency coefficient, regression parameters were also observed. Values of 'n' less than unity indicates a shear-thinning behaviour, while values greater than unity suggest a shear-thickening behaviour (Al-Malah *et al*., 4). Model with highest R^2 value was found suitable in depicting the adequate rheological behaviour of samples. Peel (fresh and dried) and peel powder were subjected to moisture analysis so as to determine the moisture percentage prior to and subsequent to drying. The moisture content of fresh peel, dried peel and peel powder samples were found to be 83.83 ± 0.37, 12.70 ± 1.25 and 12.48 ± 0.53% (w.b.), respectively.

The model parameters and regression analysis (R^2 values) of all three models used were depicted and compared for the sample with desired characteristics. The parameters related to model analysis as well as regression coefficient values after model interpretation are given in Table 1 (Herschel-Bulkey), Table 2 (Power law) and Table 3 (Casson law), respectively. $R^2 \geq 0.90$ was considered as criteria for judging a sample with required rheological features. Overall, it has been observed that the shear stress (τ) values were positively correlated with sample concentration and the same has been substantiated by model analysis.

The rheological behaviour of suspensions is affected by the sample particle size along with its distribution. Mango peel contains around 10-15% pectin on dry basis (Beerh *et al*., 5) and pectin acts as a thickener for food materials (Mesbahi *et al*., 12). Due to particle size reduction of peel powder, availability of soluble pectin increases and that might be the reason for significant increase in viscosity of the finer particle size samples. This phenomenon contributed for higher shear stress values at higher sample concentration.

Table 1. Model fitting, parameters and regression analysis through Herschel-Bulkey law.

Sample	τ (Pa)	K (Pa s^n)	n	R^2
A16	90 ± 1.90	9.86 ± 1.59	0.33	0.972
A15	2036 ± 8.65	-	0.01	0.572
A14	4937.50 ± 17.34	-	0.01	0.701
B16	64.71 ± 1.77	8.57 ± 1.42	0.57	0.996
B15	190.10 ± 1.16	9.76 ± 2.18	0.70	0.999
B14	543.82 ± 4.50	10.43 ± 4.17	0.92	0.995
C16	48.08 ± 0.34	11.68 ± 4.69	0.46	0.999
C15	115.43 ± 0.48	14.46 ± 1.65	0.57	0.999
C14	345.41 ± 3.95	60.07 ± 6.38	0.62	0.997
D16	25.47 ± 0.21	28.55 ± 7.37	0.44	0.999
D15	49.08 ± 0.27	37.44 ± 9.0	0.55	0.999
D14	101.41 ± 3.62	69.07 ± 12.86	0.64	0.997

All values are average calculated from 3 replications of each sample.

Table 2. Model fitting, parameters and regression analysis through Power law.

Sample	a	b	R^2	SD
A16	80.33 ± 23.27	0.18 ± 0.07	0.966	2.30
A15	391.27 ± 15.17	-0.01 ± 0.014	0.579	8.58
A14	738.04 ± 7.54	-0.05 ± 0.081	0.715	16.93
B16	48.98 ± 1.03	0.32 ± 0.008	0.992	2.55
B15	118.79 ± 4.13	0.27 ±0.009	0.985	6.64
B14	361.81 ± 25.07	0.16 ±0.010	0.936	17.22
C16	37.98 ± 4.83	0.35 ± 0.016	0.995	1.79
C15	76.77 ± 6.74	0.33 ± 0.005	0.993	4.19
C14	302.89 ± 36.42	0.22 ± 0.016	0.993	7.20
D16	42.88 ± 6.68	0.39 ± 0.011	0.999	0.85
D15	43.46 ± 7.68	0.37 ± 0.009	0.997	2.14
D14	133.20 ± 8.40	0.32 ± 0.028	0.996	5.03

Where, 'a' and 'b' are the regression parameters related to Power law model.
SD values are related to shear stress (τ).
All values are average calculated from 3 replications of each sample.

Table 3. Model fitting, parameters and regression analysis through Casson law.

Sample	τ (Pa)	a	B	R^2
A16	100.53 ± 2.36	9.96 ±1.16	0.34 ± 0.12	0.962
A15	354.65 ± 9.18	18.83 ± 0.19	-0.14 ± 0.04	0.515
A14	635.17 ± 19.43	25.20 ± 0.04	-0.27 ± 0.04	0.789
B16	71.09 ± 1.53	8.43 ± 0.08	0.63 ± 0.02	0.996
B15	166.09 ± 1.41	12.89 ± 0.18	0.68 ± 0.03	0.999
B14	451.29 ± 9.32	21.24 ± 0.58	0.78 ± 0.03	0.980
C16	64.73 ± 1.23	7.47 ± 0.46	0.64 ± 0.03	0.998
C15	112.65 ± 1.04	10.60 ± 0.48	0.84 ± 0.01	0.999
C14	404.47 ± 6.20	20.08 ± 1.06	0.91 ± 0.04	0.995
D16	55.95 ± 2.74	8.01 ± 0.61	0.76 ± 0.02	0.994
D15	64.33 ± 1.89	8.02 ± 0.33	0.85 ± 0.01	0.998
D14	193.89 ± 8.11	13.92 ± 0.33	1.08 ± 0.11	0.991

All values are average calculated from 3 replications of each sample.

Reduction in the average particle size of peel powder samples having similar sample concentration, decline in shear stress (τ) was reported. This may be due to the fact that particle size reduction attributed towards an increase in surface area, which helped in binding up of water molecules during rehydration. This helped in making the resultant sample homogeneously viscous and thus shear stress values decreased. Similar results were reported for apple puree (Espinosa *et al*., 7), for chest nut flour (Moreira *et al*., 13; Ahmed *et al*., 2). On the contrary, disruption of steady state properties was observed in the samples with larger particles. This was probably because of the sedimentation promoted by the instability of the internal network due to shear as also reported by Sato *et al*. (16) for jaboticaba pulp. The detailed model analysis has been represented in the forthcoming section.

Shear stress gains positively with increasing sample concentration with values ranged between 25.47 ± 0.21 to 4937.50 ± 17.34 Pa (Table 1). This trend was due to the fact that force per unit area requirement will be more for coarser particle size samples as compared to finer and homogeneously viscous samples. On the other hand, 'τ' reduces with decrease in particle size, which may be because; lesser force was required to disrupt sample structure having finer particle size. As flow behaviour index 'n' values ranged between 0.01 and 0.92, shear thinning and pseudoplastic nature for all peel powder samples was indicated. The results are in conformity with previous results obtained by Pelegrine *et al*. (14) for pineapple and mango pulps and Ahmed (1) for ginger paste.

Results showed reasonably good fitting to power law model with R^2 values 0.936 to 0.999 except for samples of 420 microns sieve. Value of regression parameter 'a' was within 37.98 and 738.04, while for 'b' it was between -0.05 to 0.39. Shear thinning flow behaviour was depicted for all samples, where n<1. Higher regression coefficient values ($R^2 \geq 0.962$) were obtained for all samples except for undersize of 420 microns sieve and this showed reasonably good fitting of data pertaining to this model. From the model interpretation, it was clear that peel powder samples have rheological characteristics over the whole sample concentration and particle size range selected. Peel powder except, which got passed through IS 420 microns, rest of the samples justified for the rheological characteristics.

The present study indicated that mango peel powder possesses rheological characteristics which differs with selected combination of sample concentration and particle size. Herschel-Bulkley, Power law and Casson models were suitable in representing the flow behaviour of the tested samples. Shear stress (τ) values were positively correlated with sample concentration and the same was indicated by model analysis. Both consistency indices and flow indices (Herschel-Bulkley law) increased with increase in sample concentration. Regression parameter 'a' and regression parameter 'b' pertaining to Power law and Casson law increased and decreased with sample concentration, respectively. With the decrease in average particle size of peel powder samples (with similar sample concentration), reduction in shear stress (τ) values was reported. As evident from model simulation and regression analysis, peel powder samples of size 420 microns were not found appropriate for further possible rheological related studies.

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REFERENCES

1. Ahmed, J. 2004. Rheological behaviour and colour changes of ginger paste during storage. *Int. J. Food Sci. Tech.* **39**: 325-30.

2. Ahmed, J., Attar, H. and Arfat, Y.A. 2016. Effect of particle size on compositional, functional, pasting and rheological properties of commercial water chestnut flour. *Food Hydrocolloids*, **52**: 888-95.

3. Ajila, C.M., Naidu, K.A., Bhat, S.G. and Prasada Rao, U.J.S. 2007. Bioactive compounds and antioxidant potential of mango peel extract. *Food Chem*. **105**: 982-88.

4. Al-Malah, K.I., Azzam, M.O.J. and Abu-Jdayil, B. 2000. Effect of glucose concentration on the rheological properties of wheat-starch dispersions. *Food Hydrocolloids*, **14**: 491-96.

5. Beerh, O.P., Raghuramaiah, B. and Krishnamurthy, G.V. 1976. Utilizaan of mango waste: Peel as a source of pectin. *J. Food Sci. Tech.* **13**: 96-97.

6. Bourne, M.C. 2002. *Food texture and Viscosity: Concept and Measurement*, Academic Press, London.

7. Espinosa, L., Toa, N., Symoneaux, Renard, C.N.G.C., Biau, N. and Cuveliera, G. 2011. Effect of processing on rheological, structural and sensory properties of apple puree. *Procedia Food Sci*. **1**: 513-20.

8. Keshani, S., Chuah, A.L. and Russly, A.R. 2012. Effect of temperature and concentration on rheological properties pomelo juice concentrates. *Int. Food Res. J.* **19**: 553-62.

9. Kim, H., Moon, J.Y., Kim, H., Lee, D.S., Cho, M., Choi, H.K., Kim, Y.S., Mosaddik, A. and Cho, S.K. 2010. Antioxidant and antiproliferative activities of mango (*Mangifera indica L.*) flesh and peel. *Food Chem*. **121**: 429-36.

10. Koubala, B.B., Kansci, G., Mborne, L.I., Crepeau, M.J., Thibault, J.F. and Ralet, M.C. 2008. Effect of extraction conditions on some physicochemical characteristics of pectins from ‘Amellioree’ and ‘Mango’ mango peels. *Food Hydrocolloids*, **22**: 1345-51.

11. Kumar, R., Manjunatha, S., Kathiravan, T., Vijayalakshmi, S., Nadanasabapathi, S. and Raju, P.S. 2015. Rheological characteristics of inulin solution at low concentrations: Effect of temperature and solid content. *J. Food Sci. Tech.* **52**: 5611-20.

12. Mesbahi, G., Jamaliana, J. and Farahnaky, A. 2005. A comparative study on functional properties of beet and citrus pectins in food systems. *Food Hydrocolloids*, **19**: 731-38.

13. Moreira, R., Chenlo, F., Torres, M.D. and Prieto, D.M. 2010. Influence of the particle size on the rheological behaviour of chestnut flour doughs. *J. Food Engg*. **100**: 270-77.

14. Pelegrine, D.H., Silva, F.C. and Gasparetto, C.A. 2002. Rheological behaviour of pineapple and mango pulps. *Lebensm.-Wiss. u. Tech.* **35**: 645-48.

15. Sato, A.C.K. and Cunha, R.L. 2009. Effect of particle size on rheological properties of jaboticaba pulp. *J. Food Engg.* **91**: 566-70.

16. Vandresen, S., Quadri, M.G.N., Souza, J.A.R. and Hotza, D. 2009. Temperature effect on the rheological behaviour of carrot juice. *J. Food Engg*. **92**: 269-74.

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