Rheological behavior of pineapple puree mixed with different types of stabilizers (gum)

Tanat Uan-On and Bernhard Senge

Technische Universität Berlin/ Department of Food Rheology, Berlin, Germany

ABSTRACT

The rheological properties of pineapple puree was investigated the effect of some selected gums. Result of rheological examination indicated, xanthan gum show the good stabilizer in comparison with guar gum and LBG, because of low flow index. G′ was higher than G″, therefore puree perform the particle system.

INTRODUCTION

Tropical Pineapple (*Ananas comosus* L.) is grown extensively in South America and south-east Asia, such as Thailand, Malaysia, Philippines and Australia. Pineapple is an important tropical fruit, particularly in fresh forms or processed product. Of these, pineapple puree devised from crushing those portions of the fruit not otherwise used and thermally processing in cans or aseptic packs, is marketed as a high value-added product[2]. More importance, Pineapple purees are used as a primary product in industry for producing fruit filling[9], pineapple juice, pineapple jam or baby food.

Hydrocolloids (e.g. xanthan, locust bean gum, carrageenan and guar gum) are generally used in food application due to their functional properties. Several studies have been carried out to quantify the rheological characteristic in food formula[5]. For example, guar gum, locust bean gum and xanthan gum have applied in fruit filling or chocolate drink in order to increase the viscosity and stability value. Rheological properties are able to be considered to be importance indicator and analysis tools to provide fundamental insights on the structure of semi-solid or liquid food[1]. The viscosity behavior of hydrocolloids can be significantly affected by variables such as shear rate, temperature pressure and time of shearing. For Newtonian fluid, at constant temperature, time and pressure, the viscosity does not depend on the shear rate. For most non-Newtonian fluid, the viscosity decrease with an increase in shear rate, giving rise is known as pseudo plasticity or shear-, thinning behavior[2, 8]. Several models have been used to characterize the flow behavior of gum solutions and among them Ostwald-de Waele and equation has been used for the determination of rheological properties of high viscous non-Newtonian fluid products.

In pineapple puree, structure stability is importance properties, because, generally, the pineapple puree without stabilizer is easily to separate the phase, due to the damage of structure after blending and freezing. The study focuses on the flow properties of pineapple puree and the effect of gum as stabilizer on these properties.

MATERIALS AND METHODS

Fresh pineapples (*Ananas comosus* L) were bought from local fruit market in Berlin. Stabilizers, such as locust bean gum, guar gum and xanthan gum, were supported by Loryma GmbH, Germany.

Process of pineapple puree

Pineapple was classified the ripening by color and texture before making puree. Pineapple puree was prepared by kitchen machine for 3 minutes at speed of number 3. After that, fiber in pineapple puree was separated by sieve (2 mm.). Pineapple puree packed in plastic bag and kept in a freezer (-20 ^{o}C) until using. Examination of technique for stabilizing the pineapple puree structure was conducted using the mixed pineapple puree with locust bean gum, xanthan gum and guar gum.

Puree with gum preparation

Pineapple puree was thawed for 4 hours. 100g. of puree was stirred for 2 minutes at 400 rpm before adding gum. All gum, such as xanthan, guar and locust bean gum, were applied to each puree sample by stirring for 10 minutes at speed of 600 rpm. The gum powder dispersed in pineapple puree directly at room temperature except samples containing locust bean gum that required high temperature (70-80 ^{o}C) in order to fully disperse.

Rheological measurements

Rheological measurements were carried out using an UDS 200 rheometer (Paar-Physica, Stuttgart, Germany) accompany with the commercial computer software (Physica®, Anton Paar GmbH, Graz, Austria-Europe). The experiments were carried out in the controlled shear stress mode equipping concentric cylinder geometry of Z3 DIN. Precise temperature control was done by a Peltier Cylinder temperature system TEZ 150P. The concentric cylinder was better choice than the cone and plate set up because the pulp in the puree tends to separate easily when tested with the latter configuration, particularly the pineapple puree that contains the high fiber and pectin[6]. Viscosity behavior of pineapple puree with guar gum, locust bean gum and xanthan gum at 0.2, 0.4, 0.6 0.8 and 1 % were measured at 20 ^{o}C (± 0.1 ^{o}K).

The rheological measurements were conducted with steady shear rate and oscillation test examination. The steady shear rate was generated for 5 phases of measurement. The first was the steady shear rate at 50 s^{-1} for 1 minute. The second phase was rest the sample at 0.1 s^{-1}. Next phase, shear rate was increase until reach 50 s^{-1} and steady at 50 s^{-1} for 1 minute on phase 4. Last phase, the shear rate decreased to 0.1 s^{-1}. Oscillation examination have been studied, using the parameters obtained from dynamic viscoelasticity tests such as, storage modulus (G'), loss modulus (G''), loss tangent (tan δ) and complex modulus($|G^{*}|$). The stress sweep tests at frequency of 1 Hz were carried out in order to investigate the viscoelastic response under oscillatory shear condition. The frequency sweep measurements under condition of linear viscoelastic response were exhibited at constant stress amplitude at range 0.1-10 Hz at temperature of 20 ^{o}C.

Rheological models

The choice of an appropriate model to relate product viscosity to concentration and shear rate depend on application. During examination, lamina flow conditions are necessary for accurate measurements, because fruit puree contain particle with non uniform size and shapes, stability may sometime difficult to achieve at either very low or high shear rate. Even thought with these complex systems of structure, generally, most puree demonstrates the non-Newtonian behavior models. Therefore, the non-Newtonian model in eqs. (1) and (2) were considered to be suitable models for describing the flow behavior of pineapple puree.

The Ostwald-de Waelle model (OW), commonly referred to the power law model (see Eq 1), has been widely suited for studies of temperature treatment examination of food product, because it gives good description of fluid flow behavior in the shear rate range that is easily measured by most rheometers. However, it exhibits poor fitting for data obtained at a wide range of shear rates. This model is in the form.

$$\tau = K \cdot \dot{\gamma}^{n} \quad (1)$$

Where τ is shear stress (Pa), K (Pa·s^n) is consistency index, γ is shear rate (s^{-1}) and n is flow behavior index. When rheological properties of food exhibit a finite yield stress; the yield term is able to be included in the Power law model to yield the Herschel-Bulkley (HB) model:

$$\tau = \tau_0 + K \cdot \dot{\gamma}^{n} \quad (2)$$

Where τ is shear stress (Pa), τ_0 is yield point (Pa), K is consistency index (Pa·s^n), γ is shear rate (s^{-1}) and n is a flow behavior index. The effective viscosity was calculated using followed equation:

$$\eta_{eff} = K \cdot \dot{\gamma}^{n-1} \quad (3)$$

RESULTS AND DISCUSSION

Comparisons of selected rhelogical models

Shear stress and shear rate data were accumulated for pineapple puree with several stabilizers, such as locust bean gum, guar gum and xanthan gum, at temperature of 20 °C. Generally, the most appropriate model for describing the flow behavior of food has been selected based on the coefficient (r). According to Table 1, the r value for both equations revealed high value, were between 0.98-0.99, but most data of τ_0 with Herschel-Bulkley model show the minus value, except pineapple puree without gum and puree with LBG at concentration of 0.2-0.4 %. This point, Ostwald-de Waele equation was used to fit the measured data to determine the one which best described the flow behavior of pineapple puree over the influence of stabilizer in pineapple puree. The change in flow parameter varied with type and quantity of gum. The most importance parameter for stability indication is the flow behavior index. Pineapple pure added locust bean gum and guar gum was able to decreased flow index value. However, Flow index increased continually, when puree adding higher concentration of gums. Thus, guar gum and locust bean gum are able to use to approving effectively stability of pineapple puree at low concentration of gums. In other hand, pineapple puree with adding xanthan gum at high concentration showed decreasing flow index to 0.140. That can describe, puree structure is more stable, when adding more xanthan gum. However, xanthan gum performed the low viscosity value. As the result, xanthan gum was suitable to improve the stability properties of pineapple puree. It can be explained, that naturally, xanthan is quit stable against degradation by acids or bases heat treatments, freeze-thaw cycles, enzymes and long mixing. Moreover, xanthan gum solution is able to over range of pH, become affect only at pH values more than 11 and less than 2.5[7]. Thus, xanthan gum was not affect with pineapple pure, which is low pH food. In comparing flow index of puree with gum and without gum show the better stability than puree without gum, even adding the small amount of gum. The consistency index of different stabilizer show the same direction of tend, that was decreased with increasing concentration. Wei et al[9] studied the shear rate-shear stress relations by power law model when guar gum, locust bean gum was added to fruit filling. According to their result, the fruit filling adding guar gum and locust bean gum increased the consistency index and decreased flow index, while adding xanthan gum decreased it. Our results indicated the similar trends for the change of flow behavior index and consistency index on locust bean gum and guar gum, but xanthan gum has showed the difference result of consistency index.

The low viscosity value of xanthan gum can be solved by using a mixed gum with galactomannan. At Table 1, mixed gum between xanthan gum and guar gum showed the good stability in pineapple and also the high viscosity. On the other hand, interaction of xanthan gum and locust bean gum in puree exhibited the good stability (low flow index), but performed the high value of yield stress in Herschel-Bulkley model, so the system of its could be described as gel system. That was because; Locust bean gum reacted more strongly, because its mannose to galactose ratio 4:1 compared with 2:1 in guar gum. Moreover, xanthan gum can be strongly reacted with locust bean gum, which is less branded than guar gum[7]. The mixed gum demonstrated the advantage of each types of gum, which showed the high viscosity as galacomannan and high stability as xanthan gum.

Parameters showed that, the viscosity value of guar and locust bean gum increased, when flow index increased. As toward results, locust bean gum and guar gum performed the good viscosity value, but the stability was not succeeded at high concentration. It can be explained that, even thought, puree with guar and locust bean gum exhibited the high viscous, but structure of them was not strong and easily to destroy. On the other hand, the viscosity of xanthan gum increased with decreased flow index. However the rate of increasing viscosity was so small in compare with guar and locust bean gum. Therefore, xanthan gum performed as good stability and strong structure, but it didn't give the good result of viscosity.

Table 1 Rheological parameter of Ostwald-de Waele model and Herschel-Bulkley model for puree with different stabilizers

Gum added	Ostwald-de Waele model					Herschel-Bulkley model					
	K ($Pa \cdot s^n$)	n -	r -	s (Pa)	η_{eff} (50/s) ($Pa \cdot s$)	τ_0 (Pa)	K ($Pa \cdot s^n$)	n -	r -	s (Pa)	η_{eff} (50/s) ($Pa \cdot s$)
Puree without gum	1.22	0.435	0.988	0.19	0.09	1.45	1.16	0.393	0.988	0.08	0.09
LBG											
0.2 %	10.06	0.238	0.998	0.24	0.301	2.52	7.49	0.29	0.999	0.06	0.312
0.4 %	12.79	0.277	0.999	0.17	0.458	0.36	12.42	0.283	0.999	0.18	0.460
0.6 %	16.57	0.312	0.993	1.32	0.697	-9.10	26.01	0.235	0.998	0.60	0.676
0.8 %	20.10	0.362	0.979	3.41	1.065	-25.94	47.26	0.202	0.997	1.09	0.938
1%	22.90	0.358	0.979	4.14	1.191	-35.49	59.93	0.183	0.998	0.88	1.040
GG											
0.2 %	4.38	0.197	0.968	0.35	0.109	-113.65	118.10	0.010	0.993	0.16	0.100
0.4 %	5.96	0.259	0.991	0.38	0.196	-12.973	19.12	0.104	0.998	0.16	0.179
0.6 %	9.54	0.289	0.987	0.88	0.361	-23.671	33.684	0.110	0.999	0.14	0.322
0.8 %	18.53	0.243	0.984	1.42	0.568	-114.86	134.20	0.045	0.999	0.26	0.502
1%	36.75	0.288	0.968	3.17	0.958	-1024.0	1062.5	0.010	0.449	8.48	0.568
XG											
0.2 %	9.64	0.197	0.937	1.09	0.230	-250.61	260.37	0.010	0.958	0.63	0.220
0.4 %	12.63	0.177	0.993	0.43	0.285	-47.08	59.89	0.046	0.998	0.19	0.270
0.6 %	15.58	0.170	0.997	0.30	0.341	-18.09	33.79	0.089	0.999	0.13	0.328
0.8 %	20.87	0.152	0.999	0.23	0.420	-11.35	32.29	0.106	0.999	0.16	0.413
1%	25.23	0.140	0.999	0.20	0.480	-4.53	29.79	0.122	0.999	0.20	0.477
XG and GG											
0.5 % + 0.5 %	32.44	0.166	0.981	1.49	1.242	-30.49	62.86	0.094	0.998	0.38	1.206
XG and LBG											
0.5 % + 0.5 %	65.26	0.085	0902	4.09	1.820	65.60	1.48	0.787	0.999	0.48	1.954

XG is xanthan gum, LBG is locust bean gum and GG is guar gum

Effect of gum concentration on shear rate and shear stress

Representative curves of shear rate versus shear stress for pineapple puree with stabilizer concentration of 0.2 to 1 % indicated shear thinning behavior (see Fig. 1 a-c). The curves in these figures represent the Ostwald-de Waele model fitted to the measured data and using a phase 5 to represent to behavior of pineapple puree with different treatments. Mizrahi[4] observed that fruit puree are frequently classified erroneously as shear thinning with zero yield stress purely from observations made when a straight line result s from the fitting of shear stress versus shear rate data on log-log coordinates.

Relationship between shear stress and shear rate on concentration of 0.2-1 % showed that the increasing shear stress rate of guar gum was highest in compare with xanthan and guar gum, when adding more concentration. Particularly, curves of concentration of 0.6 to 1 % exhibited the dramatically increase of shear stress, as can be seen the large gap between curves. Locust bean gum showed the same result as xanthan gum, but only curves of 0.6 and 0.8 %. Xanthan gum performed the steady rate of increasing, when adding more concentration.

Effect of concentration on viscosity and shear rate

The influence of gum concentration on viscosity of pineapple puree at temperature of 20 ^{o}C, was demonstrated in Fig. 2 with log of shear rate and log of viscosity. The viscosity of all treatment was decreased with the increasing shear rate and performed the linear curve as expect. That was described, that puree with gum was able to significantly affect by shear rate. Furthermore, pineapple puree was able to exhibit a flow behavior as shear thinning behavior by the viscosity decreased in accordance with power law model. (see Eq. 1) Rao[8] explained that, most fruit puree showed shear thinning behavior ($0 < n < 1$), a situation that may be regarded as an indication of breakdown of structure units in a food due to the hydrodynamic forces generated during shear.

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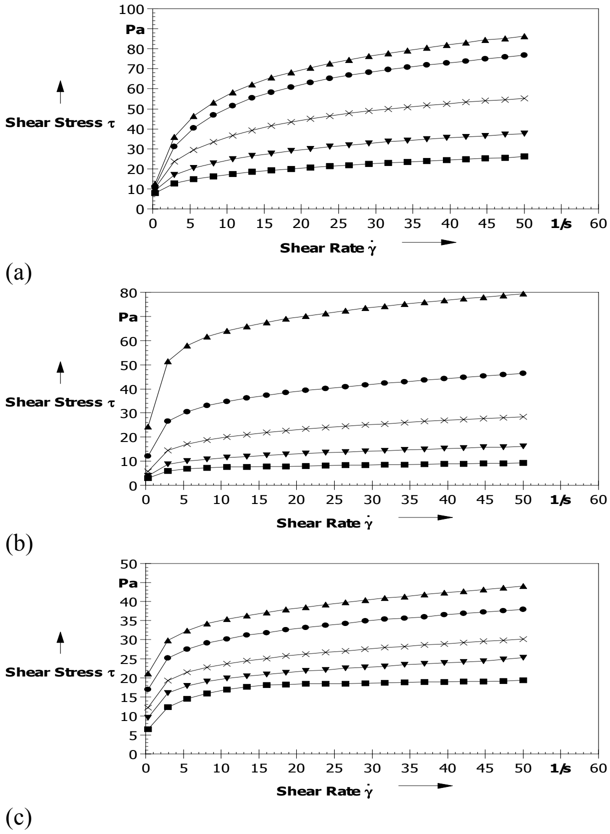


Figure 1. Relation between shear rate and shear stress for gum concentration of 0.2 % (■), 0.4 % (▼), 0.6 % (×), 0.8 % (●) and 1 % (▲) for (a) locust bean gum, (b) guar gum and (c) xanthan gum

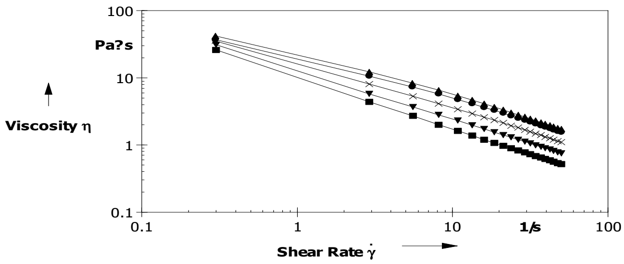
most fruit puree showed shear thinning behavior, which may be regarded as an indication of breakdown of structure units in a food due to the hydrodynamic forces generated during shear rate condition.

Effect of shear rate on viscosity revealed that, viscosity of all sample decreased significantly, when shear rate was higher. The curve of guar gum exhibited same width between each curves but there was width widely between curves in comparison with another gums. On the other hand, locust bean gum and xanthan gum showed that, the interval between diagrams was not different significantly.

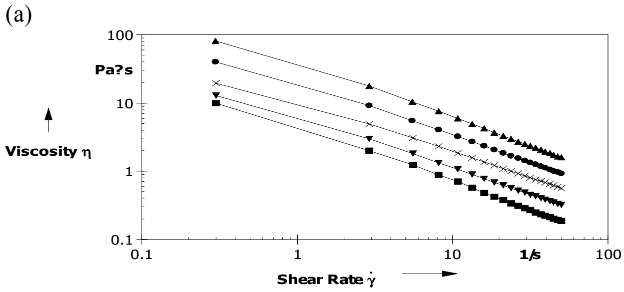
Rao[8] explained the apparent viscosity and shear rate relationships of shear thinning foods; the most shear thinning hydrocolloid exhibited the three stage viscous response when sheared over a wide shear rate range. On the first step, viscosity behavior at low shear rate showed the Newtonian behavior and transition from Newtonian to Pseudoplastic at second step. The last stage was at high shear rate showed the limiting and constant infinite shear viscous. Our result indicated the similar curve with this theory; our trend can fit in the second, because curve was decreased sharply.

Oscillation tests

Dynamic frequency sweep tests were performed in the linear viscoelastic range to determine the frequency dependence of the storage and loss modulus. Fig 3 represented the mechanical spectra of the describing viscosity of pineapple puree subjected to oscillatory deformation tests at 20 ^{o}C, obtained in the region of linear behavior. As the result of the magnitudes of both G'' and G' increased with frequency and G' was greater than G'' in the entire range of frequency. That can be described, that the predominant response of treatments to the inflicted deformation is the stored potential energy. As it could be seen from *tan* δ (G''/G'), the value of *tan* δ was less than 1 but greater than 0.1. That was explained, samples were not gel formation, but present the structure between those of concentrated biopolymer and true gel. Therefore, the characteristic of sample could indicate as a particle system as dispersion. Moreover, cross-over between G' *and* G'' have not found in the frequency sweep curve of treatments, consequently the pineapple puree with gum showed the particle system and semisolid behavior. The results of oscillation were also supported with the shear rate examination, which flow index imposed the low value as the semisolid behavior. Ahmed et al.[1] investigated the behavior of potato puree on dynamic rheological properties. Our results showed the similar trend of the dynamic frequency sweep.



(a)



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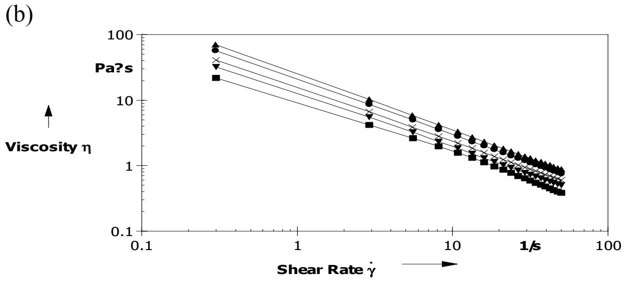


(c)

Figure 2. Relation between shear rate and viscosity for gum concentration of 0.2 %(■), 0.4 %(▼), 0.6 %(×), 0.8 %(●) and 1 %(▲) for (a) locust bean gum, (b) guar gum and (c) xanthan gum

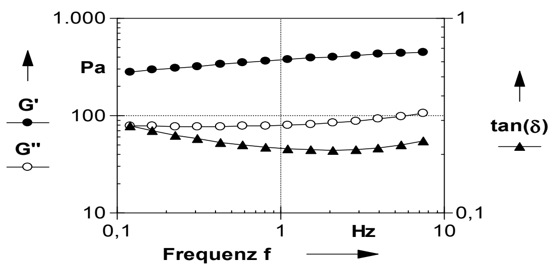
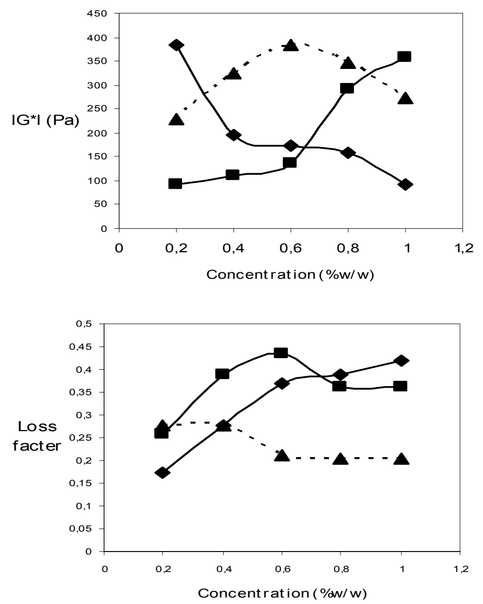


Figure 3. Dependence of storage modulus (G') (●), loss modulus (G'') (○) and loss tangent ($tan\ \delta$) (▲) for pineapple puree.

Effects of concentration on storage modulus, loss modulus and complex modulus, of pineapple puree with different gum were shown in Fig. 4a-b. The result showed that all of three gums provided particle system. The G' of locust bean gum is increased, when concentration of stabilizer is increased, but Guar gum showed the opposite trend of G'. The puree with xanthan gum promoted the highest G' at 0.6 % of concentration. The complex modulus of three types of stabilizer defined the same trend as G' parameter (see Fig. 4a-b), so the rigidity (promoted by $|G^*|$) of guar gum gave good value at high concentration of gum.



(a)

(b)

Figure 4. Effect of gum concentration on oscillation parameter at frequency of 1 Hz; comparison of locust bean gum (●), guar gum (■) and xanthan gum (▲) for complex modulus (a) and loss factor (b)

In contrast, Locust bean gum showed the good rigidity at low level of concentration. Moreover, the critical of rigidity of xanthan gum was at 0.6 % concentration.

CONCLUSION

Pineapple puree with stabilizers exhibited viscoelastic behavior with G' greater than G' in the entire of frequency range; therefore puree imposed the particle system as semisolid like. For the effect of concentration, the critical of rigidity of xanthan gum was at 0.6 % concentration as it can be clearly seen at storage and complex modulus curves. Rigidity of Locust bean gum decreased, but guar gum increased, when concentration is higher. In steady shear rate examination result, the xanthan gum imposed the good stabilizer for pineapple puree but gave the low viscosity. Guar gum exhibited also good stabilizer, but stability (as flow index value) decreased after adding more concentration of guar gum. Mixed gums were the most suitable stabilizer to apply with pineapple puree, because its can demonstrated the advantage of both gums, which were high viscosity as guar gum and high stability as xanthan gum.

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