

CHAPTER 4 RESULTS AND DISCUSSIONS

This chapter contains the results and discussions of the study of dielectric properties, i.e., dielectric constant and dielectric loss factor together with flow properties, i.e., rheological parameters of papaya puree. The effects of soluble solids contents, temperature and frequency on dielectric properties were examined and described. In Section 4.1 the frequency range from 355 to 8010 MHz were measured. Then, two microwave frequencies (915 and 2450 MHz) were focused to describe the combined effect of soluble solids contents, temperature and frequency on dielectric properties then mathematical models of dielectric properties were develop for microwave heating process that useful for industrial process improvement. Section 4.2 included the effects of soluble solids contents and temperatures on flow properties were analyzed and the empirical models were developed to predict apparent viscosity of papaya puree.

Before discussion of the experiments, the physicochemical characteristics of single strength papaya puree were reported as shown in Table 4.1.

Table 4.1 Physicochemical characteristics of single strength papaya puree 100 g

Content	Unit
Soluble solids contents (°Brix)	10.10
pH	4.84
Acidity (g citric acid/100 ml)	0.16
Water (%)	88.41
Ash (%)	0.52
Protein (%)	0.54
Fiber (%)	0.66
Fat (%)	0.06
Carbohydrate* (%)	9.81



*Calculated from [100 – water – protein – fat – fiber - ash]

From Table 4.1, the main composition of papaya puree was water. The values of water in papaya at 10, 15, 20 and 25 °Brix were 88.41, 84.25, 80.00 and 75.80 % wet basis, respectively.

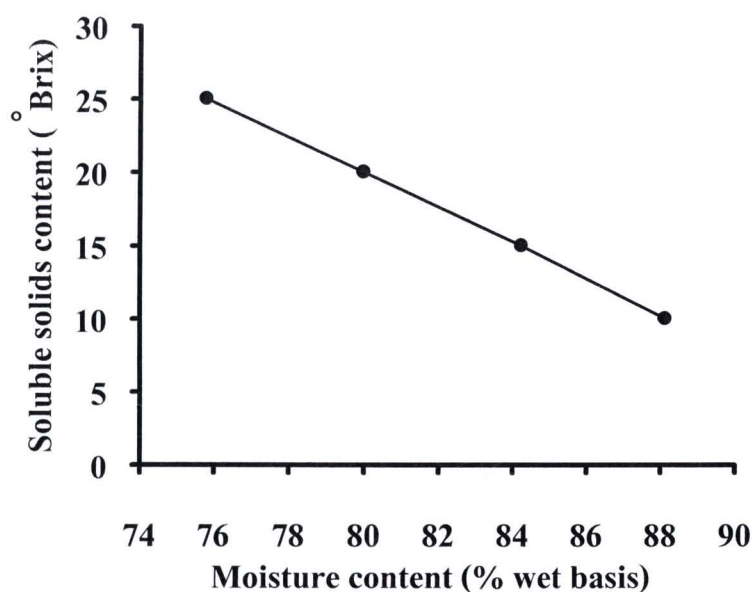


Figure 4.1 Moisture content versus soluble solids contents of papaya puree

4.1 Dielectric Properties of Papaya Puree

Dielectric properties, i.e., dielectric constant and dielectric loss factor were measured at frequency range from 355 to 8010 MHz and the effects of soluble solids contents, temperature and frequency on dielectric properties at two microwave frequencies of 915 and 2450 MHz were described in this section.

4.1.1 Effects of Soluble Solids Content, Temperature and Frequency on Dielectric Properties

Preliminary results of dielectric properties using network analyzer, Agilent Technologies N5230A 300 kHz- 13.5 GHz PNA-L Model without commercial software are shown in Appendix B.

Dielectric properties i.e., dielectric constant and dielectric loss factor versus frequencies at different temperatures i.e., 40, 50, 60, 70 and 80 °C and different soluble solids

contents i.e., 10, 15, 20, and 25 °Brix using network analyzer, Agilent technologies N5230C PNA-L model were plotted and shown in Figure 4.2 and 4.3.

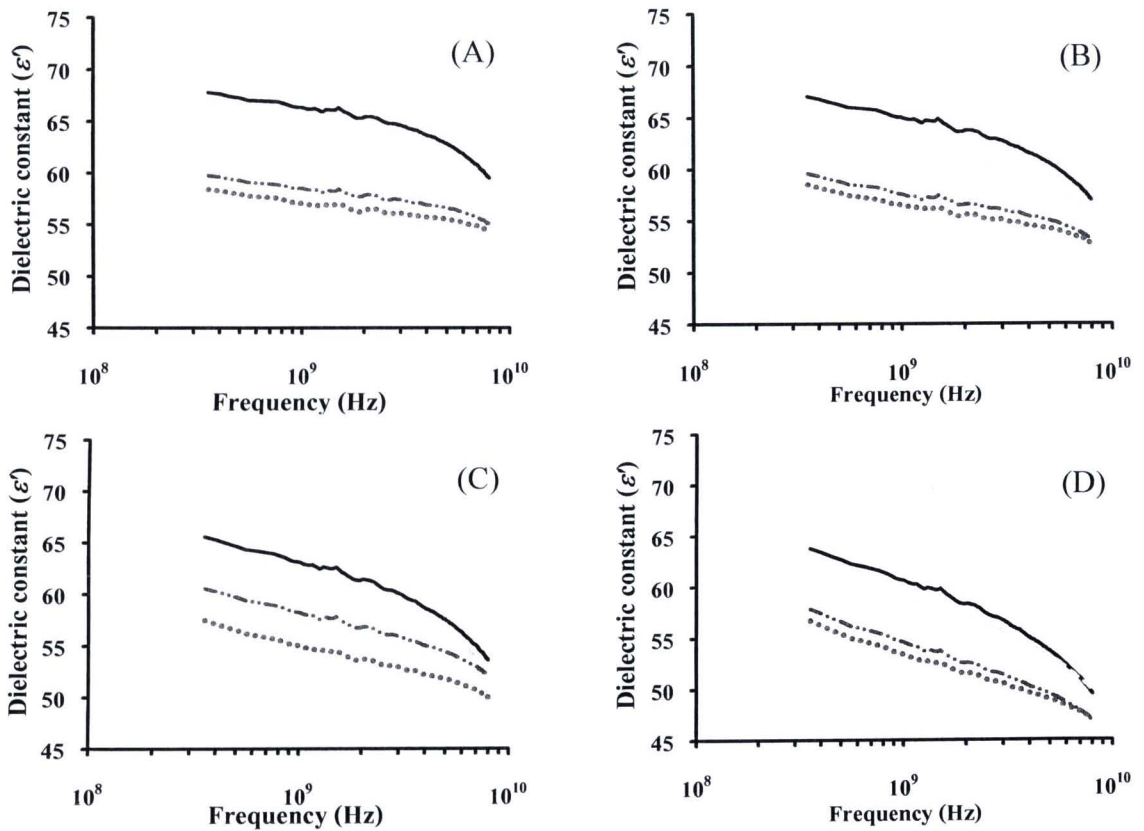


Figure 4.2 Dielectric constant of papaya puree at frequency range from 355 to 8010 MHz and different temperatures, 40 °C, — 50 °C, 60 °C, — · — 70 °C and ······ 80 °C using Network analyzer 5230C model at (A): 10 °Brix, (B): 15 °Brix, (C): 20 °Brix, (D): 25 °Brix

From Figure 4.2, it was found that dielectric constant decreased with increasing both temperature and frequency. There are two trends of dielectric loss factor as shown in Figure 4.3. At frequency range below turning point, dielectric loss factor decreased with increasing frequency but decreasing temperature. Then dielectric loss factor changed to increase with increasing frequency but decreasing temperature at frequency range above turning point. Similar trends were found in sweet potato puree (Fasina et al., 2003).

They measured the dielectric properties, i.e., dielectric constant and dielectric loss factor at frequencies of 900 to 2500 MHz and temperatures of 5 to 80 °C.

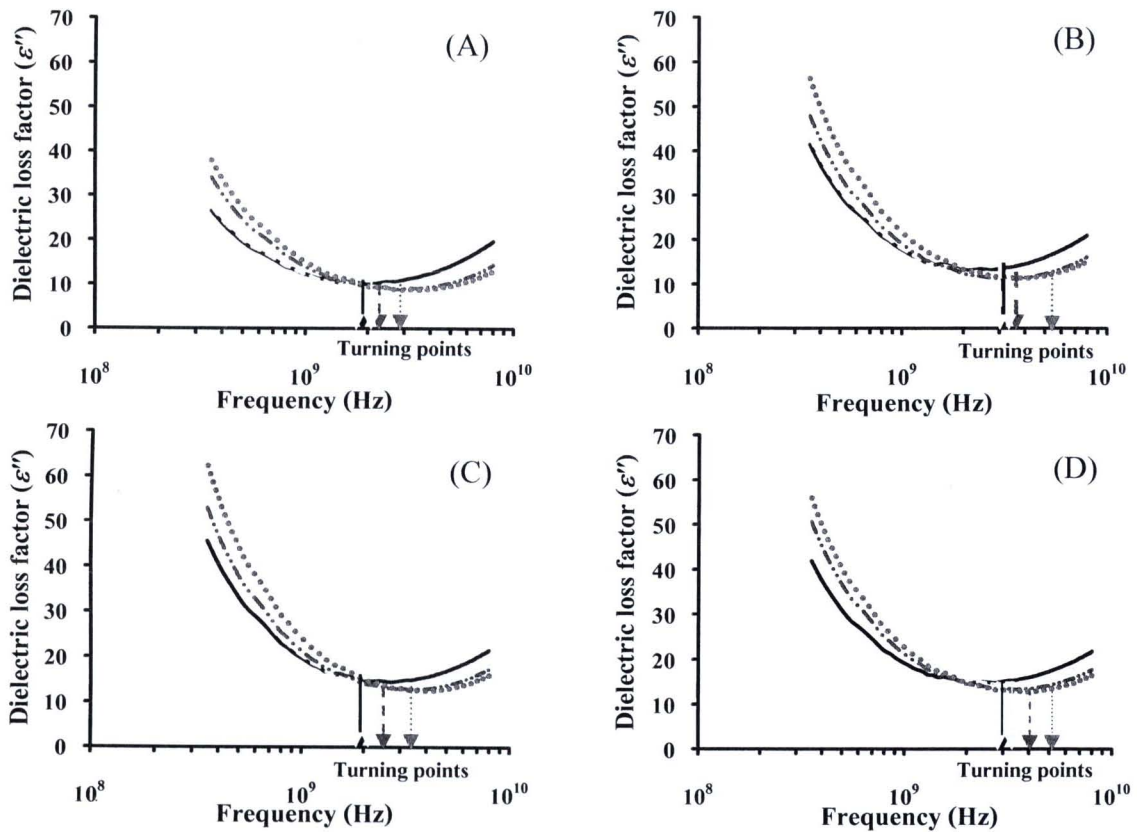


Figure 4.3 Dielectric loss factor of papaya puree at frequency range from 355 to 8010 MHz and different temperatures, 40 °C, — 50 °C, ····· 60 °C, — · — 70 °C and ····· 80 °C using Network analyzer 5230C model at (A): 10 °Brix, (B): 15 °Brix, (C): 20 °Brix, (D): 25 °Brix

Normally, dielectric loss factors (ϵ'') is composed of two components; dipole loss and ionic loss. Dipole loss results from the rotation of water dipoles, while ionic loss results from migration of ions. From Figure 4.3, at frequency range below relaxation frequency, dipole loss increased while the ionic loss decreased with increasing frequency. The combination of these two opposite effects resulted in a turning point in the plot of dielectric loss factor versus frequency. Similar results were found in yellow-

locust honey solution (Guo et al., 2011). The turning point of loss factor as a result of dipole loss and ionic loss shifted toward a higher frequency as temperature increased as shown in Table 4.2.

In general, the dielectric loss factor depends on two important effects, frequency and temperature. When the temperature increased the relaxation peak and ionic conductivity are shifted to higher frequency due to the smaller viscosity of the solution and the corresponding higher mobility of ions (Feher, 1997 and Mudgett, 1985) as shown in Figure 2.3.

Table 4.2 Frequencies at Turning Points and Dielectric Loss Factors of Papaya puree at various Soluble Solids Contents and Temperatures (using Network analyzer, Agilent Technologies N5230C PNA-L Model)

Soluble Solids Contents (°Brix)	Frequency at Turning Point (MHz)					Dielectric Loss Factor at Turning Point				
	40 °C	50 °C	60 °C	70 °C	80 °C	40 °C	50 °C	60 °C	70 °C	80 °C
10	1975	1975	2000	2005	2715	10.8	10.0	9.4	8.9	8.8
15	2000	2000	2015	2185	3430	13.7	13.1	12.7	11.2	11.3
20	2000	2000	2715	2770	3500	15.2	14.4	13.3	12.8	12.5
25	2000	2000	2715	2720	3430	15.1	14.8	14.5	13.3	12.8

Dielectric properties i.e., dielectric constant and dielectric loss factor versus temperature at microwave frequencies of 915 and 2450 MHz were plotted as shown in Figure 4.4 and 4.5, respectively.

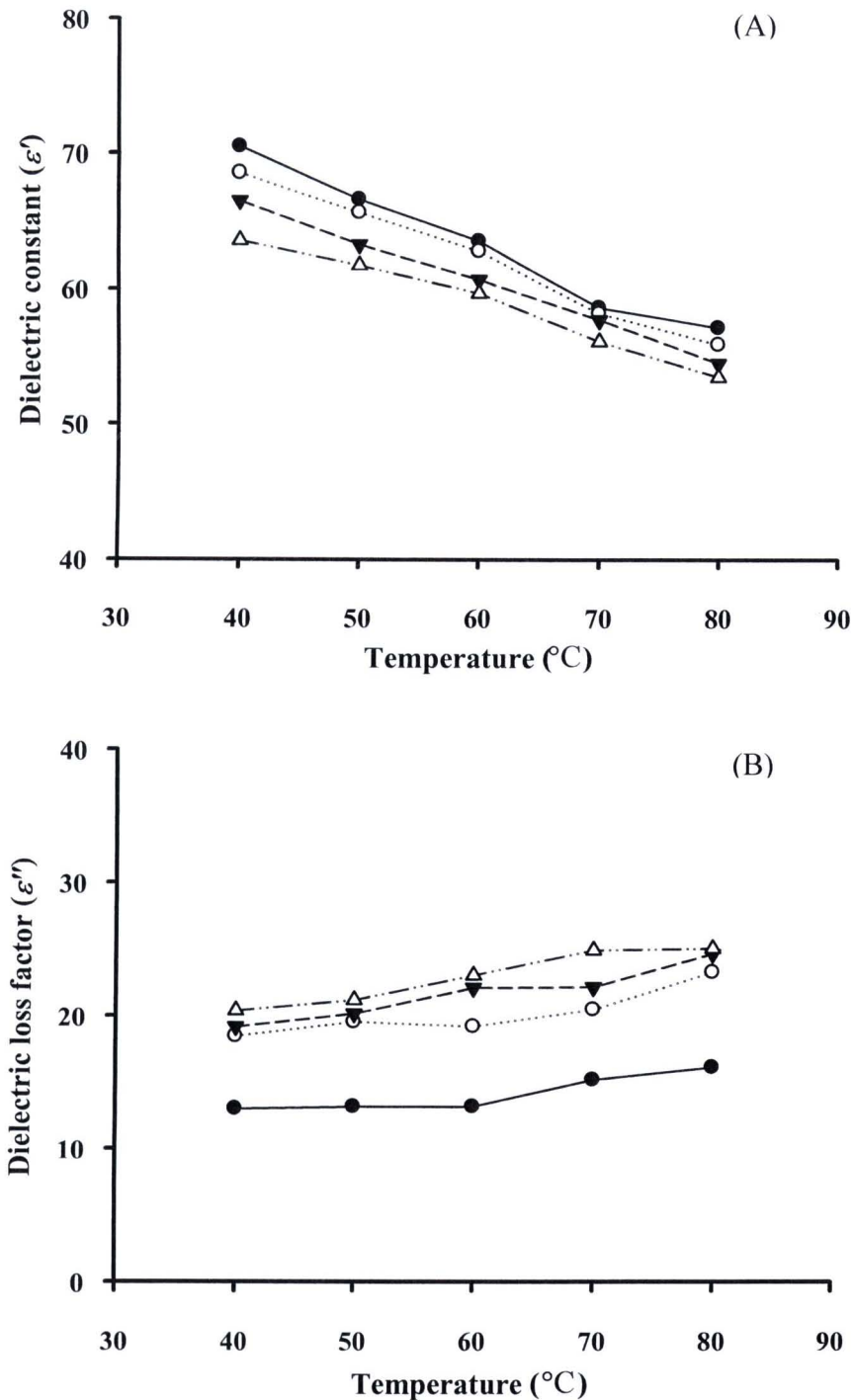


Figure 4.4 Dielectric properties, (A): dielectric constant and (B): dielectric loss factor of papaya puree at different soluble solids contents (●):10 °Brix (○):15 °Brix (▼):20 °Brix (△): 25 °Brix as a function of temperatures at frequencies of 915 MHz (Using Network analyzer, Agilent Technologies N5230C PNA-L Model)

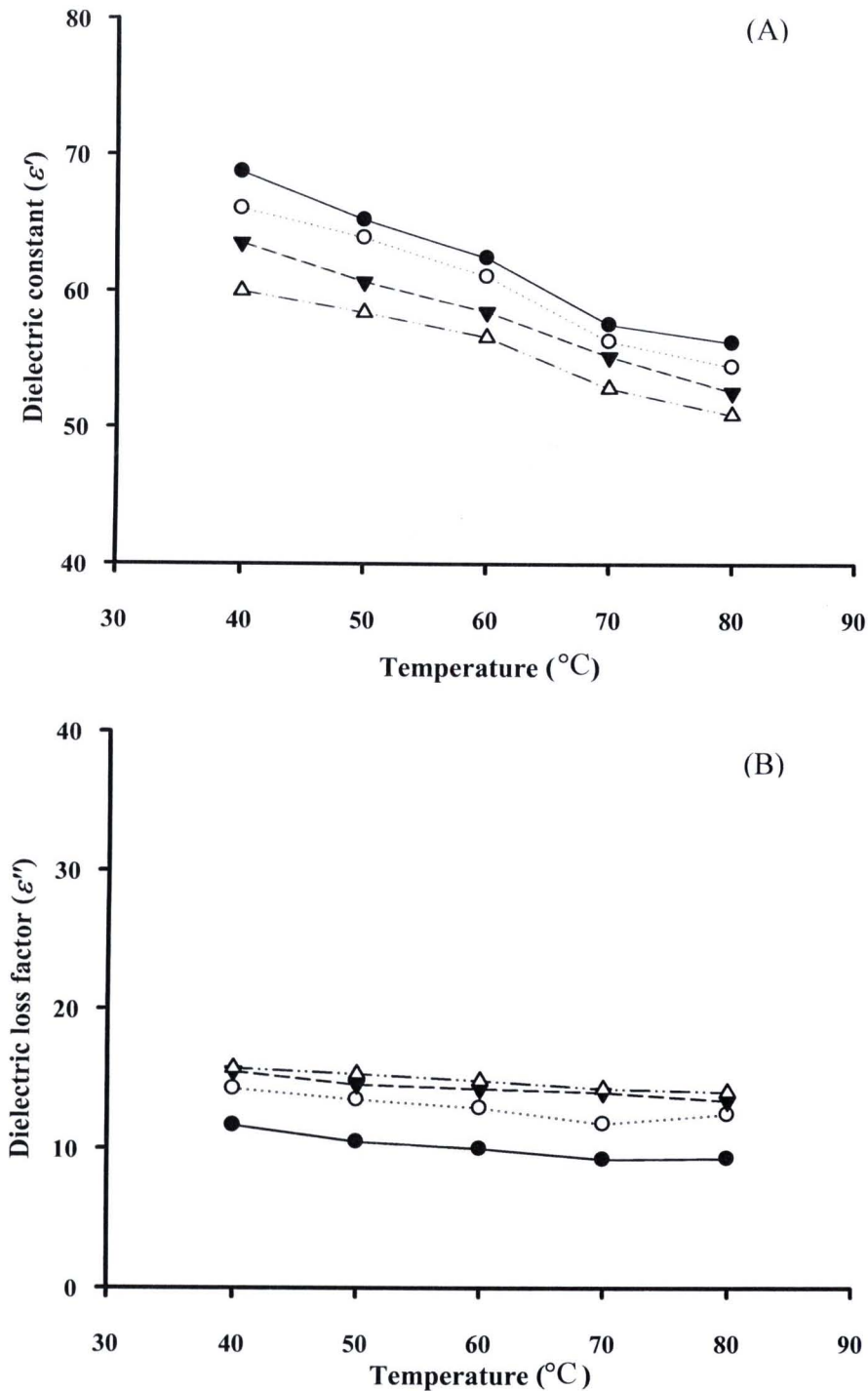


Figure 4.5 Dielectric properties, (A): dielectric constant and (B): dielectric loss factor of papaya puree at different soluble solids contents (●):10 °Brix (○):15 °Brix (▼):20 °Brix (△): 25 °Brix as a function of temperatures at frequencies of 2450 MHz (Using Network analyzer, Agilent Technologies N5230C PNA-L Model)

It was obvious from Figure 4.4 (A) and 4.5 (A) that the dielectric constant of papaya puree decreased as temperature increased while soluble solids contents decreased. In general, the dielectric constants decreased with increasing temperatures and decreasing moisture contents (Sosa-Morales et al., 2009). These results were as expected and they were in accordance with previous reports on the effects of temperature and moisture content on the dielectric constant of various food materials; mashed potato (Guan et al., 2004), carrot, parsley, spinach, radish, turnip, yam, potato, garlic, broccoli, cucumber, apple, pear, banana and corn (Sipahioglu et al., 2003) and sauce of meat lasagna (Wang et al, DOI: 10.1016/j.jfoodeng.2011.05.031). The results of their research revealed that dielectric constant of vegetables and fruits decreased as temperature increased. Because most water in vegetables and fruits exist as free water and the free water decreased as temperature increased (Mudgett, 1995). The dielectric constant of papaya puree decreased as soluble solids contents increased (or moisture contents decreased) and it was found that the dielectric constants of bi-distilled and de-ionized water were higher than the dielectric constants of papaya puree sample since water is a strong polar solvent and is a major absorber of microwave energy in the foods. Consequently, higher moisture content, the higher dielectric constant of the foods (Venkatesh et al, 2004; Tang et al, 2002).

The plotting between dielectric loss factor versus temperature at different soluble solids contents were shown in Figure 4.4 (B) and 4.5 (B). From these figures the results showed that dielectric loss factors (ϵ'') increased as temperature increased at 915 MHz but decreased as temperature increased at 2450 MHz. The results were in accordance with the theory, at frequency below turning point frequency of the lowest temperature (about below 2000 MHz), dielectric loss factor increased with increasing temperature

but at frequency above turning point frequency of the lowest temperature (about above 2000 MHz), dielectric loss factor decreased with increasing temperature. It is due to the combination effects of temperature and frequency. The results were in agreement with the previous reports on the effects of temperature on the dielectric loss factor of different food materials; Grape juice (Gracia et al., 2001), mashed potato (Guan et al., 2004), carrot, parsley, spinach, radish, turnip, yam, potato, garlic, broccoli, cucumber, apple, pear, banana and corn (Sipahioglu et al., 2003) and potato puree with different salt contents (Wang et al., 2011).

Based on Figure 4.4 (B) and 4.5 (B), it was found that dielectric loss factors (ϵ'') of papaya puree at frequencies 915 and 2450 increased as soluble solids contents increased and the dielectric loss factors of papaya puree samples were higher than dielectric loss factors of bi-distilled and de-ionized water. Generally, dielectric loss factors (ϵ'') are composed of dipole loss and ionic loss while ionic losses are the dominant term of dielectric loss factor of papaya puree. Similar trend were found in apple juices (Giraldez et al., 2010). They found that higher malic acid content of apple juice, the higher dielectric loss factor and they explained that ionic losses are the main contribution to loss factor. Moreover, Tulasidas and others (1995) found that the grape's native at lower moisture content are likely to have the higher concentration of salts compared to high moisture grapes. The contribution to ionic conductivity by these salts could explain the observed the higher loss factor in the lower moisture content samples.

4.1.2 Empirical Model of Dielectric Properties of Papaya Puree

Based on the results of dielectric properties (dielectric constant and dielectric loss factor) of papaya puree at different soluble solids contents (10, 15, 20, and 25 °Brix)

and temperatures (40, 50, 60, 70 and 80 °C) at two microwave frequencies, i.e., 915 and 2450 MHz, it was obvious that soluble solids content, temperature and frequency influenced dielectric properties. The obtained empirical models with the highest R-square (R^2) and lowest standard error (SE) for predicting dielectric constant and loss factor at two microwave frequencies (915 and 2450 MHz) were summarized in Table 4.3.

Table 4.3 Empirical model of dielectric constant and loss factor at different frequencies; 915 and 2450 MHz (network analyzer, Agilent technologies N5230C PNA-L model with commercial software)

Empirical Model	R^2	SE
$\varepsilon'_{915} = 88.8305 - 0.4540B - 0.3853T + 5.9 \times 10^{-3} B \cdot T - 5.6 \times 10^{-3} B^2 - 2 \times 10^{-4} T^2$	0.9895	0.5789
$\varepsilon''_{915} = -1.3682 + 2.0438B - 0.1273T + 3.3 \times 10^{-3} B \cdot T - 4.82 \times 10^{-2} B^2 + 1.5 \times 10^{-3} T^2$	0.9641	0.8583
$\varepsilon'_{2450} = 86.6254 - 0.5324B - 0.3435T + 6.1 \times 10^{-3} B \cdot T - 7.2 \times 10^{-3} B^2 - 4 \times 10^{-4} T^2$	0.9870	0.8239
$\varepsilon''_{2450} = 8.3912 + 1.0872B - 0.1811T + 1.06 \cdot 10^{-3} B \cdot T - 2.40 \cdot 10^{-2} B^2 + 9 \times 10^{-4} T^2$	0.9895	0.2431

4.2 Flow Properties of Papaya Puree

The effects of soluble solids content and temperature on flow curves, yield stress (τ_y), flow behavior index (n) and the consistency coefficient (K) of papaya puree were studied. The soluble solids contents of papaya puree were varied at 10, 15, 20 and 25 °Brix and the temperatures were varied at 5, 20, 35, 50, 65 and 80 °C. It was found that the flow behavior of papaya puree at different soluble solids contents and temperatures was as thixotropic (Figure 4.6). After eliminating time dependency, flow was adequately described by Herschel-Bulkley Model (Equation 2.9).

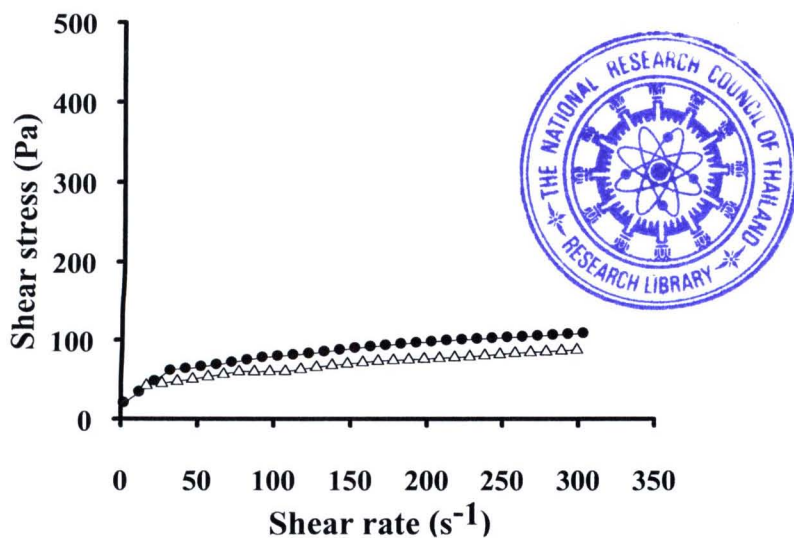


Figure 4.6 Relationship between shear stress (Pa) and shear rate (s^{-1}) of 10 °Brix papaya puree at 5°C, where (●) is up curve line and (Δ) is down curve line

$$\tau = \tau_y + K \dot{\gamma}^n \quad (2.9)$$

Where τ is the shear stress (Pa), τ_y is the yield stress (Pa), $\dot{\gamma}$ is the shear rate (s^{-1}), K is the consistency coefficient ($Pa \cdot s^n$) and n is the flow behavior index.

Table 4.4 provides the values of yield stress (τ_y), flow behavior index (n) and consistency coefficient (K) of papaya puree at various soluble solids contents ($^{\circ}$ Brix) and temperatures ($^{\circ}$ C). Shear stress was plotted against shear rate as shown in Figure 4.7. Similar trends were obtained for every condition. Moreover, the same results and trends were found in strawberry puree (Maceiras et al., 2006) and blueberry puree (Nindo et al., 2005).

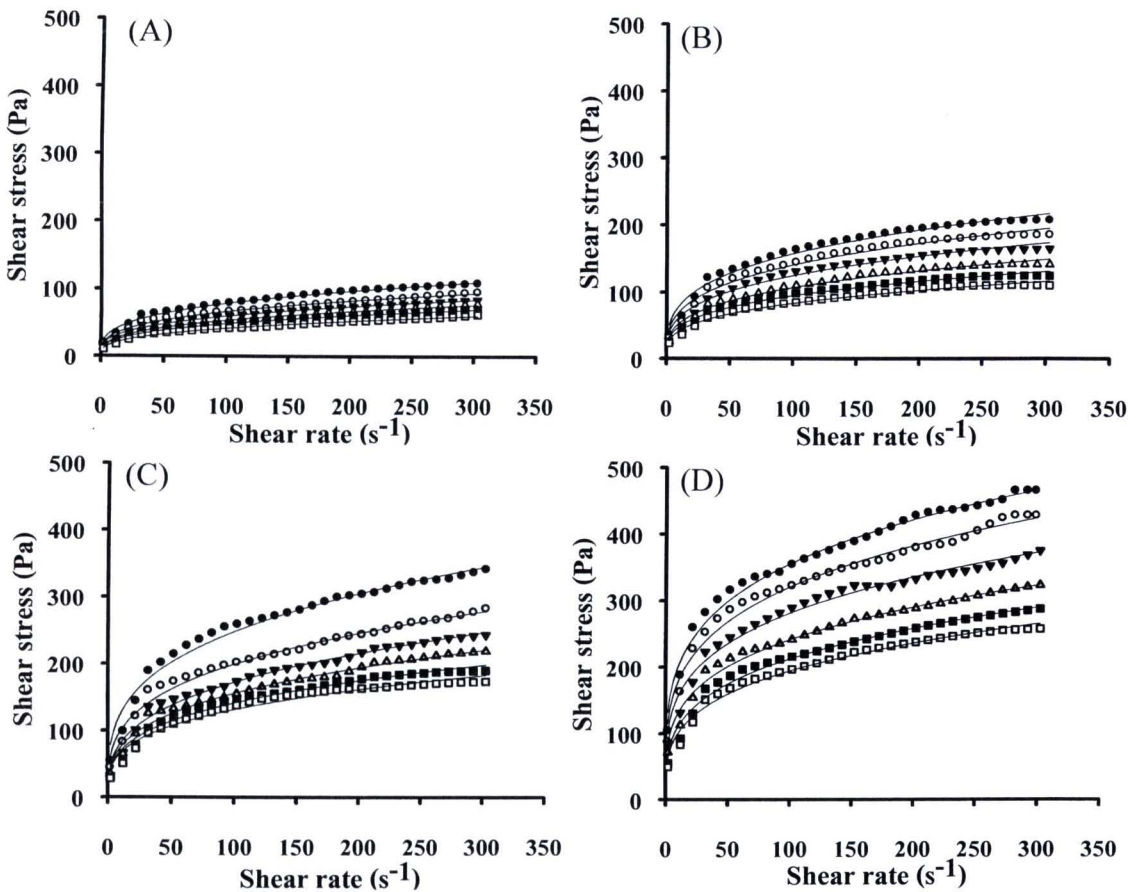


Figure 4.7 Relationship between shear stress (Pa) and shear rate (s^{-1}) of (A) 10 $^{\circ}$ Brix, (B) 15 $^{\circ}$ Brix, (C) 20 $^{\circ}$ Brix and (D) 25 $^{\circ}$ Brix of papaya puree at various temperatures, (\bullet):5, (\circ):20, (\blacktriangledown):35, (\blacktriangle):50, (\blacksquare):65 and (\square):80 $^{\circ}$ C

Apparent viscosity was calculated and plotted against shear rate as shown in Figure 4.8. The variation of apparent viscosity as a function of soluble solids content and temperature is shown in Figure 4.8. It was found that the apparent viscosity of papaya puree decreased with increasing shear rate for all samples. At the beginning, the papaya puree's particles are at equilibrium, molecules are not organized and contained pectin in structure (Guerrero, 1998), resulting in a resistance to flow. When the sufficient shear force is applied, the inter-particle linkages are broken, resulting in reduction in the size of structural units that, in turn, offer lower resistance to flow during shear (Mewis, 1979). After a sharp reduction of viscosity, the viscosity changed slightly and became steady at higher shear rate. This can be related to the reduction in size of colloidal aggregates as the shear rate increased (Ibanoglu, 2002).

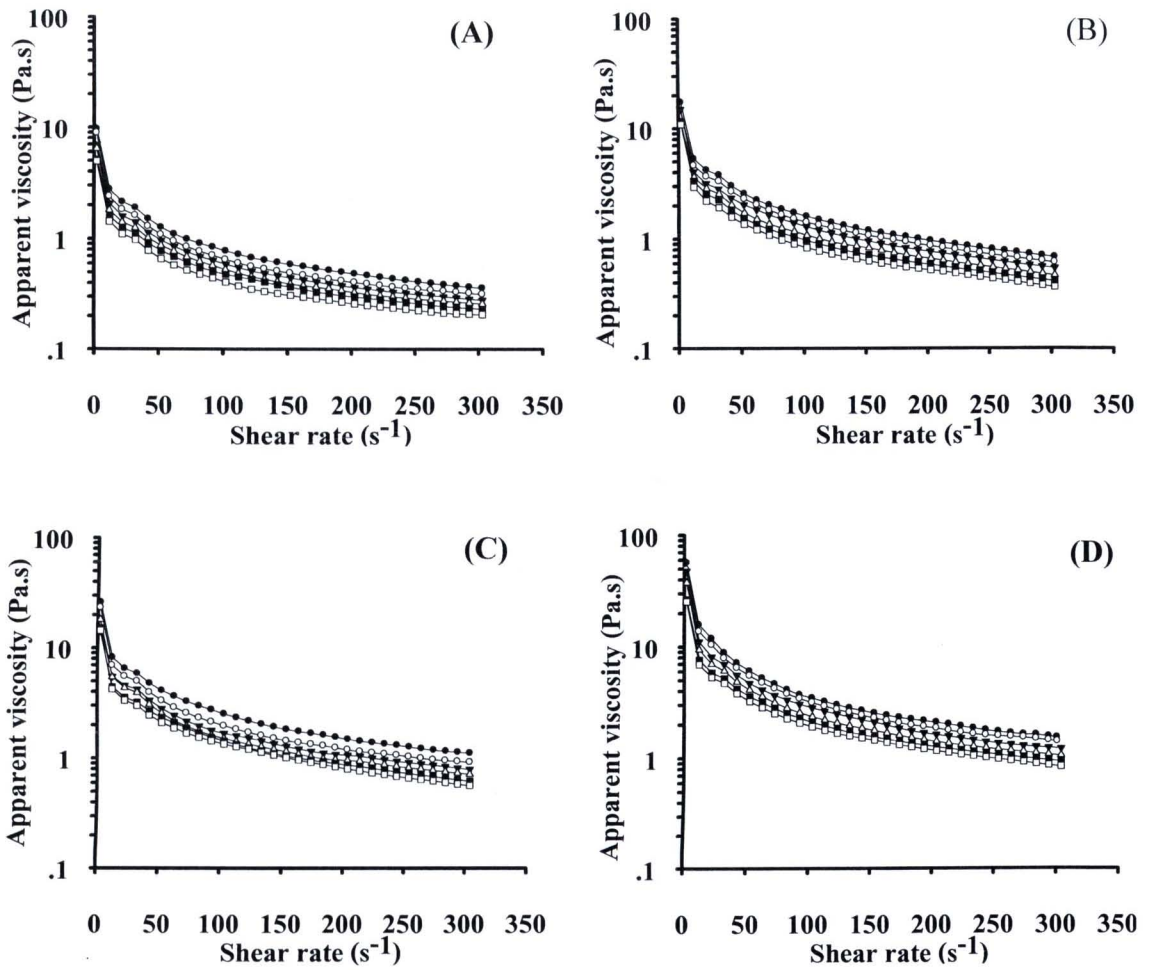


Figure 4.8 Relationship between apparent viscosity (Pa.s) and shear rate (s⁻¹) of (A) 10 °Brix, (B) 15 °Brix, (C) 20 °Brix and (D) 25 °Brix papaya puree at various temperatures, (●):5, (○):20, (▼):35, (△):50, (■):65 and (□):80 °C

Table 4.4 Yield stress (τ_y), flow behavior index (n) and consistency coefficient (K) of papaya puree at various soluble solids contents ($^{\circ}$ Brix) and temperatures ($^{\circ}$ C)

TSS ($^{\circ}$ Brix)	Temp ($^{\circ}$ C)	Yield stress, τ_y (Pa)	Flow behavior index, n (-)	Consistency coefficient, K (Pa·s n)
10	5	19.773	0.472	6.440
	20	16.880	0.473	5.434
	35	15.127	0.483	4.630
	50	12.396	0.487	4.196
	65	11.033	0.494	3.704
	80	10.114	0.501	3.007
15	5	35.447	0.446	15.118
	20	30.317	0.451	13.332
	35	26.673	0.467	10.985
	50	25.300	0.462	9.410
	65	23.980	0.468	8.091
	80	22.603	0.495	5.980
20	5	53.887	0.450	23.610
	20	44.190	0.438	20.128
	35	32.047	0.450	17.183
	50	34.410	0.450	14.894
	65	28.420	0.465	12.729
	80	27.743	0.467	11.550
25	5	104.077	0.432	34.427
	20	87.380	0.440	30.882
	35	85.336	0.439	24.952
	50	71.350	0.438	21.893
	65	54.987	0.445	19.593
	80	48.907	0.450	17.628

From Figure 4.8, the results show that the apparent viscosity of papaya puree was decreased with increasing temperatures. The apparent viscosity of papaya puree heated at 80 $^{\circ}$ C was lower than heated at lower temperatures (5, 20, 35, 50 and 65 $^{\circ}$ C). Because the random Brownian motion of the particles is affected by temperature (Petrowski,

1976). This motion is slower, the viscosity and the resistance are higher at the lower temperature due to particle collision.

Some food such as concentrated grape juice (Arslan, Yener, & Esin, 2005), pineapple (Kaya & Belibagli, 2002) and mango pulps (Pelegrine et al., 2002) behave as thixotropic fluid. This behavior can be attributed to structural changes in the sample due to the generated hydrodynamic forces and the consequent alignment of the molecules in the flow direction (Alpasalan & Hayta, 2002). The particles or molecules in foods are linked together by weak forces (Mewis, 1979) resulting in a resistance to flow. When sufficient shear force is applied to achieve flowing, that is yield stress. From the results (Table 4.4), the consistency coefficient and yield stress increased with increasing soluble solids content but decreasing temperature. The consistency coefficient is identified the viscous nature of the system.

The apparent viscosity of papaya puree with 25 °Brix (the highest soluble solids content in this research) was higher than those of papaya puree with 10, 15, 20 and 25 °Brix (lower soluble solids contents). The same trend was found in other researches, which were heather honey (Witczak et al, 2011), blueberry puree (Nindo et al., 2005) and peach, papaya and mango puree (Guerrero et al., 1998). The presence of a large number of molecules increased the resistance, resulting in increasing apparent viscosity of papaya puree. Therefore, at low soluble solids content, there are fewer molecules than at high soluble solids content the particles can flow easily, resulting in decreasing viscosity.

The consistency coefficient (K) is an indicator of the viscous nature of the material. From Table 4.4, the results present that K increased with decreased in temperature. This result indicated a reduction in apparent viscosity at high temperature. The same trend of the effect of temperature on consistency coefficient was found in other purees and jam (Merceiras et al, 2007) and Siriguela pulp (Augusto et al., DOI: 10.1016/j.jfoodeng.2011.08.015). However, the effect of soluble solids content on consistency coefficient (K) was opposite as compared to effect of temperature. The results showed that consistency coefficient (K) increased with an increase in soluble solids contents. The presence of a large number of molecules also increases the resistance to flow which, in turn, increases the apparent viscosity of sample. Gratao et al. (2003) and Guerrero et al. (1998) observed the same trend; consistency coefficient (K) increased as soluble solids contents of soursop juices and fruit purees increased.

The data of flow behavior index (n) are shown in Table 4.4. The magnitudes of value of flow behavior index were between 0.432 and 0.501. These values were close to the results of other studies (Guerrero et al., 1998). Considering the effects of temperature and soluble solids content on flow behavior index (n), it was observed that flow behavior index (n) increased slightly with increasing temperature but decreased with increasing soluble solids content. Similar trends were reported by Merceiras et al. (2007) for fruits purees, Gratao et al (2003) for soursop juices and Chin et al. (2009) for pummelo juice. However, the effects of temperature and soluble solids content on flow behavior index were not significant at 95% confident.

4.2.1 Effect of Temperature on Apparent Viscosity

Based on the results of Table 4.5, the apparent viscosity of the papaya puree was highly dependent on the temperature. The effect of temperature on apparent viscosity at specific shear rate of the power law model of a fluid is described by Arrhenius relationship (Equation 2.14).

$$\eta_a = \eta_{\infty A} \exp(E_a/RT) \quad (2.14)$$

Where η_a is the apparent viscosity at specific shear rate (Pa.s), $\eta_{\infty A}$ is viscosity at infinite shear rate, E_a is the activation energy (kJ mol^{-1}), R is the gas constant ($\text{kJ mol}^{-1} \text{K}^{-1}$) and T is Temperature (K).

The parameters, $\eta_{\infty A}$ and E_a can be estimated by taking natural logarithm into Equation (2.14) as following;

$$\ln \eta_a = \ln \eta_{\infty A} + \frac{E_a}{RT} \quad (2.15)$$

The apparent viscosity data at the specific shear rate 300 s^{-1} (Pa.s) are shown in Table 4.8. When the logarithm of apparent viscosity was plotted versus reciprocal absolute temperature ($1/T$), a straight line was obtained with high R^2 (0.991-0.997) and the estimated value of $\eta_{\infty A}$ and E_a at different soluble solids contents and temperatures are shown in Table 4.6.

Table 4.5 The apparent viscosity at 300 s^{-1} (Pa·s) of papaya puree at various temperatures and soluble solids contents.

TSS [°Brix]	Temperature [°C]	Apparent Viscosity at 300 s^{-1} (η_{app}) [Pa·s]
10	5	0.360
	20	0.316
	35	0.280
	50	0.258
	65	0.232
	80	0.206
15	5	0.686
	20	0.613
	35	0.545
	50	0.469
	65	0.414
	80	0.366
20	5	1.125
	20	0.935
	35	0.806
	50	0.725
	65	0.628
	80	0.573
25	5	1.642
	20	1.488
	35	1.240
	50	1.069
	65	0.952
	80	0.836

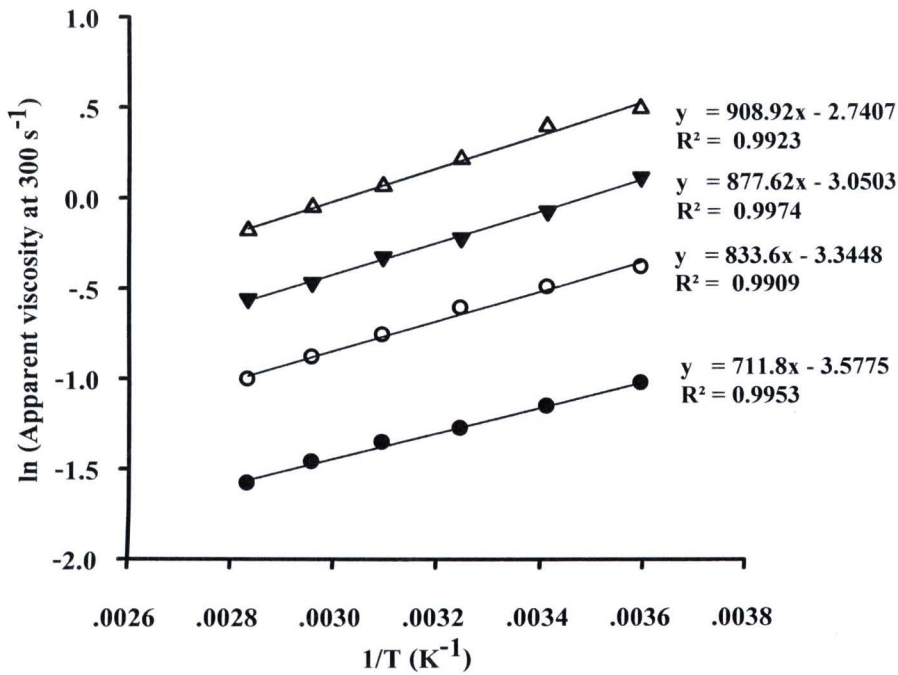


Figure 4.9 $\ln(\text{apparent viscosity})$ versus temperature of papaya puree samples at (●):10 °Brix, (○):15 °Brix, (▼):20 °Brix and (△):25 °Brix obtained from Arrhenius relationship

Table 4.6 Parameters of Arrhenius model ($\eta_{\infty A}$ and E_a) from the effect of temperature

TSS (°Brix)	$\eta_{\infty A}$ (Pa.s)	E_a (kJ/mol)	R^2
10	0.028 ± 0.006	5.918 ± 0.538	0.995
15	0.035 ± 0.007	6.931 ± 0.547	0.991
20	0.047 ± 0.009	7.297 ± 0.529	0.997
25	0.065 ± 0.010	7.557 ± 0.310	0.992

The viscosity of the liquids usually decreases with increasing temperature and such a dependent is normally described by Arrhenius model (Dak et al, 2006 and Quintas et al, 2006).

For non-Newtonian fluids, the viscosity should be considered at specific shear rate in order to evaluate the temperature effect. In this work, a shear rate of 300 s^{-1} was considered.

From Table 4.6, viscosity at infinite ($\eta_{\infty A}$) and activation energy (E_a) values increased with increasing soluble solids content. This meant that the higher soluble solids content cause an increase in the resistance to flow of the papaya puree sample. The activation energy (E_a) values of papaya puree at various soluble solids contents (10 – 25 °Brix) were between 5.918 - 7.557 kJ/mol. These values were similar to the results of other puree; pear (7.95 kJ/mol) and peach (7.11 kJ/mol) at 16 and 11.7 °Brix, respectively (Rao, 1986). However, the activation energy of papaya puree was slightly lower than those of some fruits puree; banana puree (18 ± 1) and mango puree (30 ± 2) at 28-51 °Brix, pH3 and temperature range 10-55 °C (Guerrero and Alzamora, 1998). The same trend was found as other fruits puree, the activation energy for blueberry puree increased as soluble solids content increased. At soluble solids contents between 10 - 65 °Brix the activation energies of blueberry puree were between 9.14 and 39.15 kJ/mol; while that of raspberry juices were between 12.2 and 41.2 kJ/mol (Nindo et al, 2005).

4.2.2 Effect of Soluble Solids Content

In most foods, the soluble solids content plays an important role in the rheological properties.

The effect of soluble solids content on apparent viscosity can be described by either exponential or power law relationships.

The effect of soluble solids content on apparent viscosity of heather honey described very well by power law model (Witczak et al, 2011) and the frozen concentrated orange juice (FCOJ) can be described by exponential relationships (Rao et al, 1984).

Power law model

$$\eta_a = a \cdot C^b \quad (2.16)$$

Exponential model

$$\eta_a = d \exp(e \cdot C) \quad (2.17)$$

Where η_a is the apparent viscosity at specific shear rate (Pa.s), C is the soluble solids content ($^{\circ}$ Brix) and a , b , d and e are constants of the models.

From the result of plotting the apparent viscosity versus soluble solids content, it was found that the power law model was better data than Exponential model. The parameters of power law model a and b were shown in Table 4.7

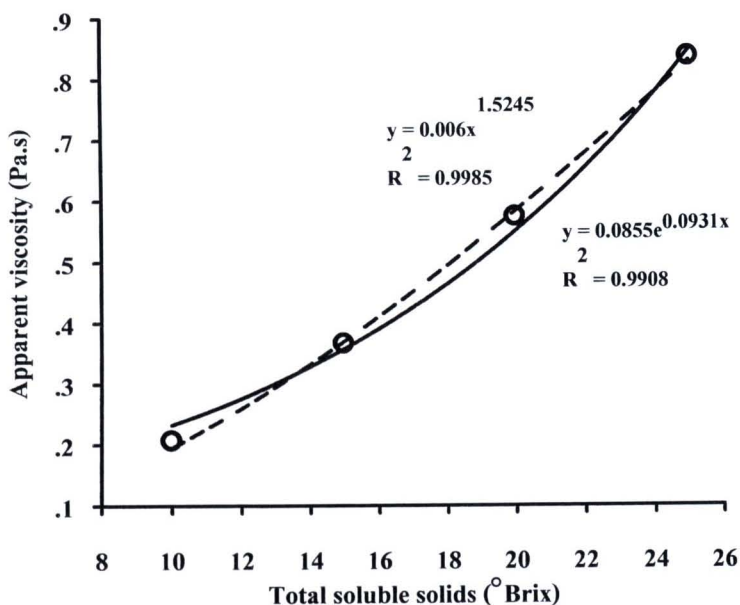


Figure 4.10 The apparent viscosity at 80 $^{\circ}$ C versus soluble solids content

Table 4.7 The parameters value of power law and exponential model of papaya puree for the effect of soluble solids content on the apparent viscosity

Temperature (°C)	Power			Exponential		
	<i>a</i> (Pa.s)	<i>b</i> (°Brix ⁻¹)	R ² (1)	<i>d</i> (Pa.s)	<i>e</i> (°Brix ⁻¹)	R ² (2)
5	0.0078	1.6588	0.9996	0.1404	0.1010	0.9862
20	0.0068	1.6599	0.9964	0.1223	0.1014	0.9894
35	0.0071	1.5969	0.9971	0.1140	0.0972	0.9841
50	0.0074	1.5399	0.9987	0.1069	0.0940	0.9899
65	0.0018	1.9629	0.9884	0.0959	0.0931	0.9926
80	0.0006	1.5399	0.9985	0.0855	0.0931	0.9908

4.2.3 Combined Effects of Soluble Solids Content and Temperature

The combined effects of temperature and soluble solids content on the apparent viscosity of power law model are described by Equation (2.18).

$$\eta_a = a \cdot C^b \exp(E_a/RT) \quad (2.18)$$

$$E_a = A \cdot C^B \quad (2.20)$$

Where η_a is the apparent viscosity at specific shear rate (Pa.s), C is the soluble solids content (°Brix), T is absolute temperature (K) and a , b , A and B are constants of the models.

This equation was used in the computation of the apparent viscosity as a function of temperature and soluble solids content. The constants a , b , A and B can be predicted by taking natural logarithm into Equation (2.18) and excel program was used to calculate these values and the proposed model was shown in Equation (4.1).

$$\eta_a = 0.0034C^{0.8946} \exp(3246.7C^{0.2681}/RT) \quad (4.1)$$

From Equation (4.1), the main factors that influencing apparent viscosity were soluble solids content and temperature and the constant of a , b , A and B were 0.0034 (Pa·s), 0.8946 ($^{\circ}\text{Brix}^{-1}$) 3246.7 (J/mol· $^{\circ}\text{Brix}$) and 0.2681 ($^{\circ}\text{Brix}^{-1}$), respectively with high R-square (0.9984).