

# Rheological Properties of Some Fruit Spreads

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**Abstract:** Rheological properties of three Smooth homogenized spreads were evaluated at different shear rates ( $2.29 - 34.35 \text{ s}^{-1}$ ) using Brookfield rotational viscometer (DVIII Ultra). The spreads were prepared from purees of three fresh fruits, (Guava, Banana and Strawberry). To 100 g of puree; 1 g citric acid, 2 g sugar, 10 g water and 1g of a thickening agent were added and the mixture was homogenized. Xanthan, guar and carboxy methyl cellulose (CMC) gums were used for making three guava spreads, whereas xanthan only was used for making banana and strawberry spreads. Different rheological models were fitted to the data. The effect of temperature on rheological properties of guava, banana and strawberry spreads was studied. All fruit spreads, exhibited non-Newtonian pseudoplastic behavior. Herschel-bulkley (HB) model was the best fit (i.e. highest  $R^2$ ) for data of guava and strawberry spreads followed by Casson and Power law models. Bingham model showed higher values for yield stress of all spreads than those of HB model, whereas those of Cassons' were the least. Guava spread containing xanthan was more viscous than those containing guar or CMC. In general, spread viscosity decreased as temperature was increased. Heat penetration tests conducted on xanthan-containing spreads packed into flexible PA/PE pouches suggested possible use of such pouches for packaging fruit spreads. Xanthan-containing spreads when subjected to sensory evaluation gained satisfactory scores or butter which indicated panelists' appreciation for the new products.

**Keywords:** Fruit Spread, Rheological Models, Viscosity, Heat Penetration, Sensory

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## 1. Introduction

Food industry has shown an increased interest in producing ready – to – use convenient as well as healthier and more natural food products. Fruit and vegetable products provide consumers with their daily needs from important micronutrients such as vitamins, minerals and dietary fibers.

Additives of hydrocolloidal nature such as carboxy methyl cellulose (CMC), xanthan and guar gums may be added alone or in blend to fruit and vegetable juices and nectars in order to avoid pulp separation and precipitation as well as to improve body and extend storage time. The type and level of these additives affect viscosity and flow properties of the final product (Zeher and Van Coillie, 1992; Rabie, et al., 1999; Rabie, 2000).

Alvarez, and Canet, (2013) studied the flow behavior of vegetable-based infant purees at different temperatures ( $5 - 65^\circ\text{C}$ ) giving particular attention to the time-dependent properties in a shear rate range ( $5 - 200 \text{ s}^{-1}$ ). Power law model parameters describing flow behavior of samples depended on kind of infant puree, its water content and temperature. The

authors concluded that infant purees exhibited thixotropic behavior for all temperatures tested.

Most of pouches which have been used for thermal food processing consist of 3 film layers such as polyester, aluminum foil, and cast polypropylene (Griffin, 1987). Nowadays, there are many forms for flexible pouches which are in use for packaging food products which require in-pack thermal processing and, in the meantime, withstand retorting conditions.

The effect of different thermal and mechanical treatments, including high-pressure homogenization, on the microstructural and rheological properties of carrot, broccoli and tomato dispersions was studied by Lopez - Sanchez, et al., (2011). The authors reported that carrot and broccoli showed a different behavior from tomato under the conditions studied. Changing the order of thermal and mechanical treatment led to microstructures with different flow properties. The resulting microstructures differed in the manner of cell wall separation: either breaking across the cell walls or through the middle lamella. It was found also that high-pressure homogenization decreased the viscosity of

carrot and broccoli dispersions, while it increased the viscosity of tomato. Cryo-scanning electron microscopy showed that the cell walls of carrot and broccoli remained as compact structures after homogenization whereas tomato cell walls were considerably swollen.

Morales-Blancas et al., (2002) studied the thermal inactivation kinetics of peroxidase (POD) and lipoxygenase (LOX) from broccoli (*Brassica oleracea* L., florets) and carrots (*Daucus carota* L., cv Chantenay, cortex and core) extracts in order to optimize the blanching process in vegetables, reducing the process time and thus minimizing the loss of nutritional and sensory properties. Kampis, et al., (1984) proposed a carotene bleaching system related to POD activity which was observed in the water-soluble fraction of tomato extracts. Thermal inactivation kinetic studies in POD and LOX enzymes in the range of 70 to 100°C have clearly shown biphasic curves which are thought to depend on the presence of iso-enzymes with different thermal stabilities.

Guerrero and Alzamora, (1997) studied the effect of pH, temperature and glucose addition on flow behaviour of Banana purée. All the formulated purees were shear-thinning fluids with appreciable yield stress values and the flow curves essentially followed the Herschel-Bulkley model. Glucose addition generally decreased the apparent viscosities and increased the temperature dependence of the flow properties. No pattern was observed with respect to the effect of pH,  $a_w$ , and temperature on the flow index.

Coronel et al., 2005 reviewed the problems associated with thermal processing magnitude and technique of high viscous vegetable products such as sweet potato purees because of their low thermal diffusivity (Smith, et al., 1982) in addition to poor thermal conductivity (Fasina et al, 2003) which restricts selection of container type and size (Lopez, 1987) and leads to prolonged thermal treatment which adversely affects product quality and nutritional value.

Sharoba et al., (2012) found that addition of hydrocolloids (guar, xanthan and arabic gums) and sweeteners (Aspartame and Stevioside) affected flow behavior of papaya-apricot nectar blends. They reported that viscosity was a function of temperature and the dissolved solid concentration i.e. viscosity was dependent on the intermolecular distances of nectar constituents. As the temperature is increased, the intermolecular distances increase and therefore the viscosity will decrease. Nectar samples showed non-Newtonian pseudoplastic with yield stress fluids as the apparent viscosity decreases with increasing shear rate, therefore they exhibit a shear-thinning behavior. The pseudoplasticity increased by hydrocolloids addition and decreased by sweeteners addition. Flow behavior index of nectar samples decreased with the increasing temperature.

Maceiras et al., (2007) studied the rheological behavior of different fresh or cooked fruits (raspberry, strawberry, peach and prune). Fruit purees showed a non-newtonian behaviour and the apparent viscosity is influenced by cooking because it decreases with the temperature and increases with the sugar content. As a result, the fruit jams have a higher viscosity than fruit purees. Ostwald Waele (Power Law) and Herschel–

Bulkley rheological models fitted reasonably well the experimental data at all temperatures. They reported that the yield stress and the consistency coefficient decrease with the temperature while the flow behaviour index increases with increasing the temperature.

Ditchfield, et al., (2004) carried out experiments on banana puree at temperatures ranging from 30 to 120°C. The shear stress values ranged from 10 to 170 Pa and the shear rate values from  $10^{-5}$  to  $10^{-3}$  s<sup>-1</sup>. Herschel-Bulkley model best fitted the experimental data at all temperatures. There was a usual tendency for the apparent viscosity to decrease with increasing temperature but an increase in apparent viscosity with increasing from 50 to 60°C and from 110 to 120°C was found. That was attributed by the authors to an interaction of polysaccharides present in banana puree.

Ahmed, J. (2007) attributed the effect of temperature on the dynamic rheological characteristics of vegetable and fruit purees to gelatinisation or denaturation which substantially affect rheological properties, resulting in abnormality from general trends being exhibited. Steady flow behavior showed that vegetable and purees samples behaved as non-Newtonian fluids with definite yield stress. Shear stress-shear rate data adequately fitted the Herschel- Bulkley model.

The objective of this paper is to evaluate the rheological of purees of three fresh fruits (Guava, strawberry and Banana) and study the heat penetration of spreads packed into flexible PA/PE pouches.

## 2. Materials and Methods

### 2.1. Materials

Three fresh fruits; banana, guava and strawberry were purchased from Dokki outlets for Ministry of Agriculture products. Banana (*Musa cavendishii*), guava (*Psidium guajava* L.) and strawberry (*Fragaria ananassa*). Three edible gums; xanthan, guar, and Carboxy methyl cellulose-Na (CMC) were donated by MIFAD, Misr Food Additives, Badr City; Egypt. Citric acid was obtained from El-Gomhoria Company, El-Swah, Cairo, Egypt. Transparent Polyamide/Polyethylene (PA/PE) film (thickness, 125  $\mu$ ) was obtained from Arab Company of Pharmaceutical Packages. Physical and mechanical properties of PA/PE film were summarized in Table (1).

**Table (1).** Physical and mechanical properties of PA/PE film.

Properties	Unit <sup>1</sup>	PA/PE
Physical		
Thickness	micron	125
Weight of m <sup>2</sup>	g/m <sup>2</sup>	24.0
Heat sealing temp.	°C	140
Clarity		transparent
Printability		medium
Mechanical		
Elongation	%	263
Impact strength	N/cm <sup>2</sup>	1570

Source: Arab Company of Pharmaceutical Packages.

PA/PE = Polyamide/Polyethylene. N/cm<sup>2</sup> = Newton per square centimeter.

## 2.2. Methods

### 2.2.1. Preparation of Fruit Spreads

The fresh fruits were washed and inedible parts were discarded. Banana was peeled and divided into small disks, carrots were cut into thin disks, and strawberry were cut into quarters. Steam blanching was carried out for each fruit for 10 minutes or until texture is tender. Fruits were drained and left to cool then pureed in a home blender. The smooth purees were sieved through a fine strainer to discard fines, coarse fibers and large particles. 100 g puree; 1 g citric acid, 2 g sugar, 10 g water and 1g of a thickening agent were added. Xanthan, guar and Carboxy merthyl cellulose (CMC) were used for making three guava spreads, whereas only xanthan gum was used for making the banana and strawberry spreads. The mixture was homogenized at a speed of 6000 rpm for 3 min. Spreads were filled into glass jars, deaerated and kept refrigerated till same or second day for evaluation.

### 2.2.2. Rheological Properties of Fruit Spreads

A Brookfield Digital Rheometer, Model DV-III Ultra with Rheocalc v3.1 software (on an IBM computer for automated control and data acquisition) was utilized to evaluate the rheological properties of the fruit spreads. The sample was placed in a 100 ml beaker, the HA-06 spindle was used, and shear rate and shear stress were calculated according to the equations provided by the manufacturer (Anon, 1993). A thermostatic water bath provided with the instrument was used to regulate sample temperature. The rheological properties for fruit spreads were evaluated at temperature 25, 40 and 60 °C, and at increasing rate of shear (2.29 – 34.35 s<sup>-1</sup>) which correspond to rotational speeds of 10-150 rpm.

### 2.2.3. Evaluation of the Rheological Properties of Fruit Spreads

Guava spreads containing different gums were rheologically evaluated at 25°C, whereas guava puree or banana and strawberry spreads were evaluated at 25, 40 or 60°C. Different rheological models were used to fit the collected rheological data. The following models have been used to evaluate the rheological data:

1. Newtonian model:

$$\tau = \mu \dot{\gamma} \quad (1)$$

2. Bingham plastic model:

$$\tau = \tau_0 + \mu \dot{\gamma} \quad (2)$$

3. Power law model:

$$\tau = K \dot{\gamma}^n \quad (3)$$

4. Casson model:

$$\sqrt{\tau} = \sqrt{\tau_0} + K \sqrt{\dot{\gamma}} \quad (4)$$

5. Herschel-Bulkley model:

$$\tau = \tau_0 + K_{HB} \dot{\gamma}^n \quad (5)$$

Where,  $\tau$  is the shear stress (Pa),  $\dot{\gamma}$  is the shear rate (s<sup>-1</sup>),  $\mu$  is the Newtonian viscosity (Pa.s),  $K$  is the consistency coefficient (Pa.s<sup>n</sup>),  $n$  (dimensionless) is the flow behavior index, and  $\tau_0$  is the yield stress (Pa). The simplest of all is the Power Law model (Harper and El Sahrighi, 1965).

### 2.2.4. Evaluation of Heat Penetration Properties of Fruit Spreads

Fruit spreads containing xanthan were packaged (45 g) into PA/PE flexible pouches of 120 x 40 mm inner dimensions and sealed under light vacuum. A thermocouple probe (type RTD temperature probe, DVP-94Y, Brookfield Co.) was inserted into the pouch through a hole made near the top edge of the pouch to reach the position of the coldest point of the packed spread i.e. the pouch geometric center. The pouch was submerged in a thermo-regulated water bath (Brookfield Co.) of 85 °C. The change in temperature within the package was recorded against time till it reaches 80 °C, then the whole set was removed from the water bath and submerged in running cold water at 27 °C. Thermal data were recorded till the inner package temperature reaches 30°C. Cumulative lethality was calculated as total area of Lethal rate per minute vis. Time curve of heating and cooling phases of the heat treatment.

### 2.2.5. Sensory Attributes Were Evaluated for Fruit Spread Samples

Twelve panelists were asked to evaluate the organoleptic attributes (Color, consistency, texture, smell, taste and general acceptability) of the spreads as unacceptable, acceptable, or excellent. The frequency of each response was calculated and expressed as percentage of total responses for each sensory attributes.

### 2.2.6. Data Handling and Statistical Analysis

Data collected were summarized using the Microsoft Excel program. The same software was used for model fitting calculation and plotting data for graphical presentation. Analysis of variance was conducted using the SPSS Statistical Software Package v.11.5. Regression analyses were used to study the degree of fit of different rheological model to the rheological data and to calculate model parameters. The goodness of fit;  $R^2$ , probability of the F-value and magnitude of Mean Square error were used to study the degree of model fitness, however, only  $R^2$  was reported as they were found interrelated. Comparisons among the main treatment means were made using L.S.D test at ( $P = 0.05$ ) (Snedecor and Cochran, 2013).

## 3. Results and Discussion

### 3.1. Effect of Temperature on the Rheological Properties of Guava Purees

Fig. (1 A) depicts the effect of increasing shear rate on apparent viscosity of guava puree at 40 and 60°C. Guava puree showed lower viscosity at the higher temperature and possessed a decrease in apparent viscosity. The results

observed that Guava puree exhibited non-Newtonian pseudoplastic behavior. Differences in viscosity values between the two tested temperatures decreased as rate of shear was increased. Fitting the data to the well-known rheological models; Bingham (Fig. 1 B), Power Law (Fig. 1 C), and Herschel-Bulkley (Fig. 1 D) indicated that the later two showed higher  $R^2$  values i.e. more goodness of fit than that of Bingham. The yield value of guava puree was higher at 40°C than at 60°C which indicated less energy input is needed to initiate flow of the puree at higher temperature.

### 3.2. Effect of Adding Thickening Agent on the Rheological Properties of Guava Spread

Guava spread containing xanthan possessed higher viscosity values than those spreads containing guar or CMC gum (Fig. 2 A). It is also noticeable from Fig. (2 A) that all guava spreads exhibited non-Newtonian pseudoplastic properties. Herschel-Bulkley model showed better fit to the data than Power Law or Bingham i.e. confirming the existence of yield stress. The data were fitted to Bingham (Fig. 2 B), Power Law (Fig. 2 C), and Herschel-Bulkley (Fig. 2 D) and Casson (Table 2) rheological models. Herschel-Bulkley model showed best fit (recording highest values for  $R^2$ ) followed by Casson model for guava spread regardless the type of gum. Guava spread containing CMC showed  $R^2 = 0.99$  for power law, Guar-spread  $R^2 = 0.987$  for Bingham model. This indicated the non-Newtonian thixotropic behavior with existence of yield stress for all the types of gums. The value of yield stress was higher for guava spread containing xanthan than that containing guar gum whereas guava spread containing CMC recorded the least values for these models considering a yield stress value.

### 3.3. Effect of Temperature on Rheological Properties of Banana Spread

Fig. (3 A) depicts the effect of increasing the shear rate on viscosity of banana spread at 25, 40 and 60°C. The banana spread possessed non-Newtonian pseudoplastic behavior for all tested temperature. However, data of the banana spreads at 60°C did not fitted well to any of the models. The better fit was noticeable for banana spread at 40°C followed by that measured at 25°C.

### 3.4. Effect of Temperature on Rheological Properties of Strawberry Spread

The effect of increasing the shear rate on apparent viscosity of strawberry puree at 25, 40 and 60°C was depicted on Fig. (4 A). The strawberry spread possessed non-Newtonian pseudoplastic behavior with existence of yield stress at all tested temperature. HB shows best fit followed by Casson and Power Law models. The yield stress was higher at 40°C than at 25°C, whereas least value was at 60°C for HB model the same trend was noticeable for Bingham and Casson models but with less magnitude of the differences.

The parameters  $k$ ,  $n$  for the rheological models for the studied fruit spreads and their regression values are shown in Table (2).

Spreads (guava and strawberry) containing xanthan were fitted well to Herschel and Bulkly followed by Casson and Power Law models particularly for strawberry and guava spreads. Banana spread recorded the least  $R^2$  among all spreads for all fitted models, and therefore, the least data fit to all models. The power  $n$ ; the flow behavior index, of Power Law model of the three spreads containing xanthan gum were far lower than their counterparts of HB model. As  $n$  gets closer to 1.0 the fluid possess Newtonian attribute.

Table (2) indicated differences in the values of yield stress for the three spreads as calculated by different models. Bingham model possessed larger yield stress values than HB model. Casson model recorded the least yield stress values.

### 3.5. Sensory Evaluation of Xanthan Containing Banana, Guava and Strawberry Spreads

Fig. (5) depicts the percentages of panelists response to sensory attributes of banana, guava and strawberry spreads containing 1% xanthan gum. With respect to color attribute of the fruit spreads, only 14.1% or less scored color of the three spreads unacceptable. Color of banana spread was scored accepted by 75% of the panelists, whereas color of guava and strawberry was scored excellent by 85 and 75% of the panelists, respectively.

Consistency of the spreads was scored excellent by 50% of the panelists for banana spread, 62% for strawberry spread and 71.4% for guava spread (Fig. 5). None of the panelists scored consistency attribute unacceptable. On the contrary, 42.9% of panelists' responses to texture of guava puree were unacceptable. Texture attribute of banana and strawberry spreads scored excellent by 50% of the panelists.

None of the panelists scored smell attribute unacceptable for any of the three spreads. The smell attribute was evaluated excellent by 85.7% of panelist's responses for guava spread, 75% for strawberry spread and 50% for banana spread. Taste was scored unacceptable by only 12.5% and 14.3% of the panelists for banana and guava spreads, respectively. Taste attribute was scored excellent by 57.1%, 37.5% and 25% of the panelists for guava, strawberry and banana spreads, respectively. The general acceptability attribute was scored either acceptable or excellent by the panelists. This attribute was acceptable for banana spread by 62% of the panelists and was scored excellent by 62% and 71.4% of the panelists for strawberry and guava spreads, respectively.

It can be concluded from evaluation of the organoleptic attributes that guava spread gained the highest scores followed by strawberry spread followed by banana spread, except for the texture attribute which scored unacceptable (grainy) by 42.9% of the panelists. This can be attributed to the process of homogenization which should be more effective with guava spread otherwise a more fine sieve should be used in order to discard grainy particles.

### 3.6. Heat Penetration of Xanthan Containing Banana, Guava and Strawberry Spreads

Figure (6) depicts the temperature of the cold point (A) and the lethality rate per minute (B) of the three fruit spreads packed in the PA/PE flexible pouch during the heating and cooling process. The temperature of the cold point in the center of the strawberry spread pouch increased gradually till it reached 80°C (177°F) within 5.5 min. The content of the package was cooled to 40°C (104°F) within 2.5 min. i.e. 8 min total process time. The calculated cumulative lethality of this heat treatment was 1357 (area under the lethality curve), which can be considered sufficient to inactivate the strawberry spread endogenous enzymes and sterilize contents of the pouch.

The temperature of the cold point in the center of the guava spread pouch increased gradually till it reached 80°C (177°F) within 6.5 min. The content of the package was cooled to 40°C (104°F) within 4.7 min. i.e. 11.2 min total process time. The calculated cumulative lethality of this heat treatment was 1611.7 (area under the lethality curve), which can be considered sufficient to inactivate the guava spread

endogenous enzymes and sterilize contents of the pouch.

The temperature of the cold point in the center of the banana spread pouch increased gradually till it reached 80°C (177°F) within 6.5 min. The content of the package was cooled to 40°C (104°F) within 3.7 min. i.e. 10.2 min total process time. The calculated cumulative lethality of this heat treatment was 655.6 (area under the lethality curve) which is far lower than those of guava and strawberry spreads. The larger the area under the lethality curve the more heat received by the product.

The difference in heating rates and cumulative lethality among fruit spreads could be attributed to the difference in the fruit type i.e. its constituents and to their interaction with the thickening agent; xanthan gum which affected spread consistency (viscosity) and the heat penetration pattern. This was evident from the aforementioned rheological results. The flexible pouch with its small size, thin wall and cylindrical shape does not hinder heat penetration and thereby less process time is needed to achieve the same pasteurization or sterilization of packaged products, i.e. it preserves nutrients, sensory quality and saves time and cost of the heating process (Lopez, 1987 and Morales-Blancas *et al.*, 2002).

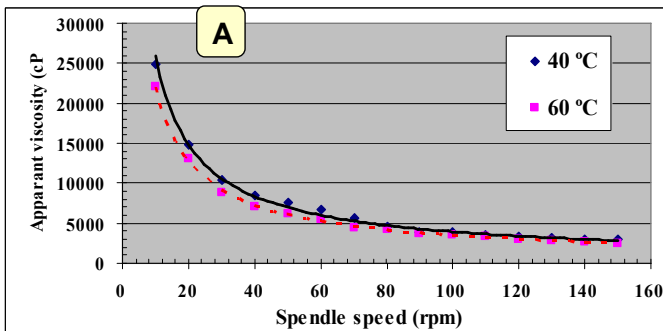


Fig. (1 A). Apparent viscosity of guava puree measured at increasing spindle rotational speed at 40 and 60 C.

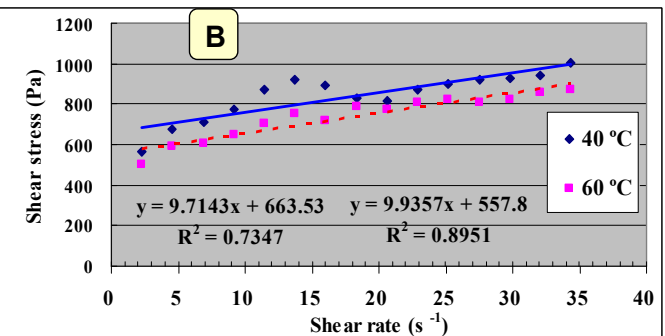


Fig. (1 B). Shear stress shear rate data of guava puree at 40 and 60 C fitted to Bingham model.

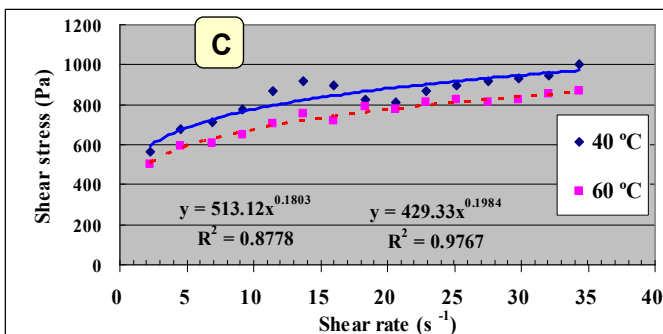


Fig. (1 C). Shear stress shear rate data of guava puree at 40 and 60 C fitted to Power Law model.

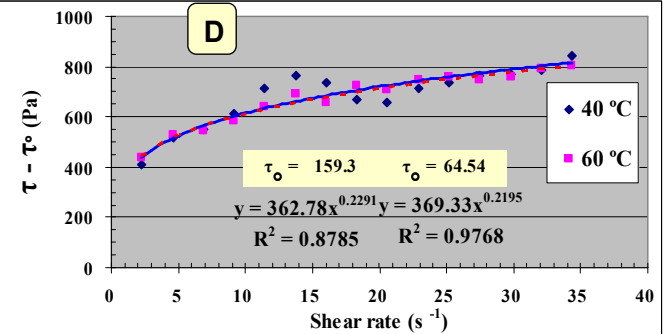


Fig. (1D). Shear stress - yield stress ( $\tau - \tau_0$ ) vis. shear rate data of guava puree at 40 and 60 C fitted to Herschel-Bulkley model.

Figure (1). Rheological data of guava puree and equations for fitted models; Bingham [B], Power law [C], and Herschel-Bulkley [D] at 40 and 60°C.

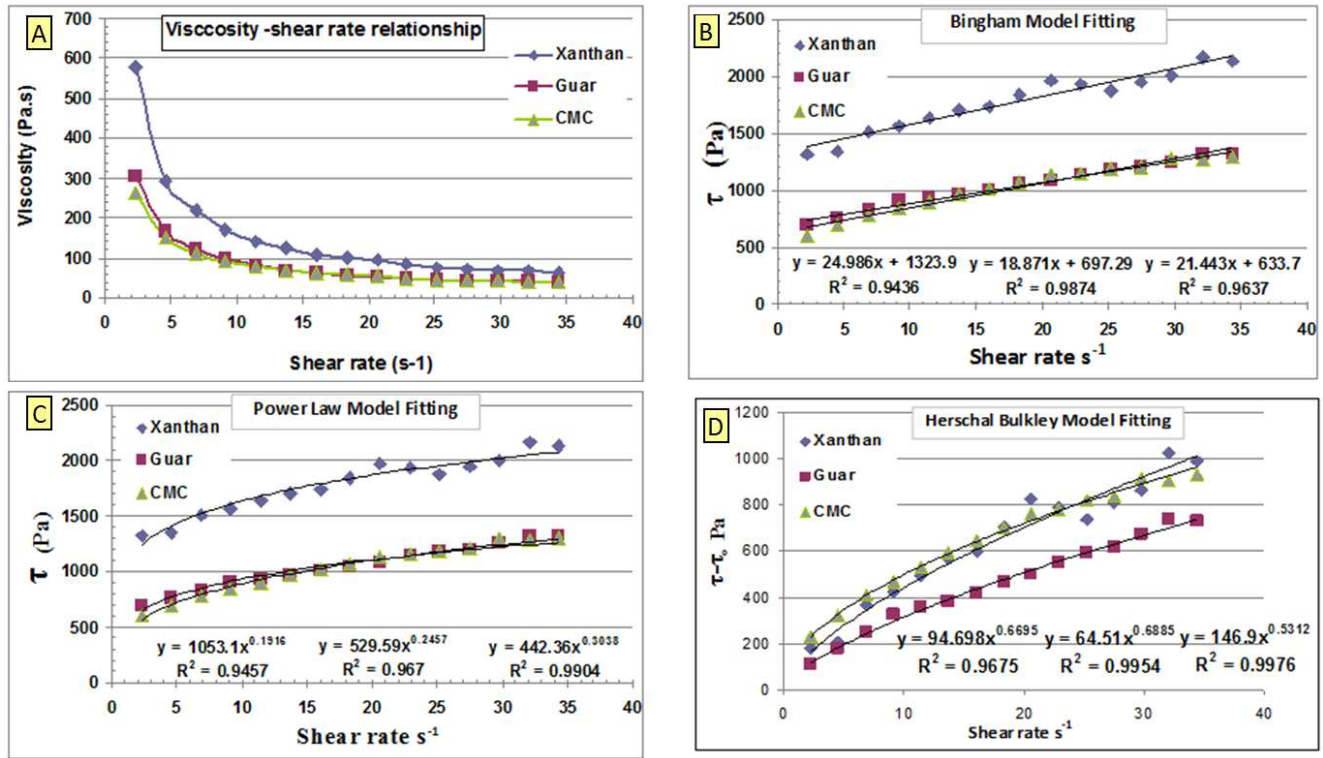


Figure (2). Rheological data of guava spreads and model constants calculations (B; Bingham; C Power law; D; Herschel-Bulkley models).

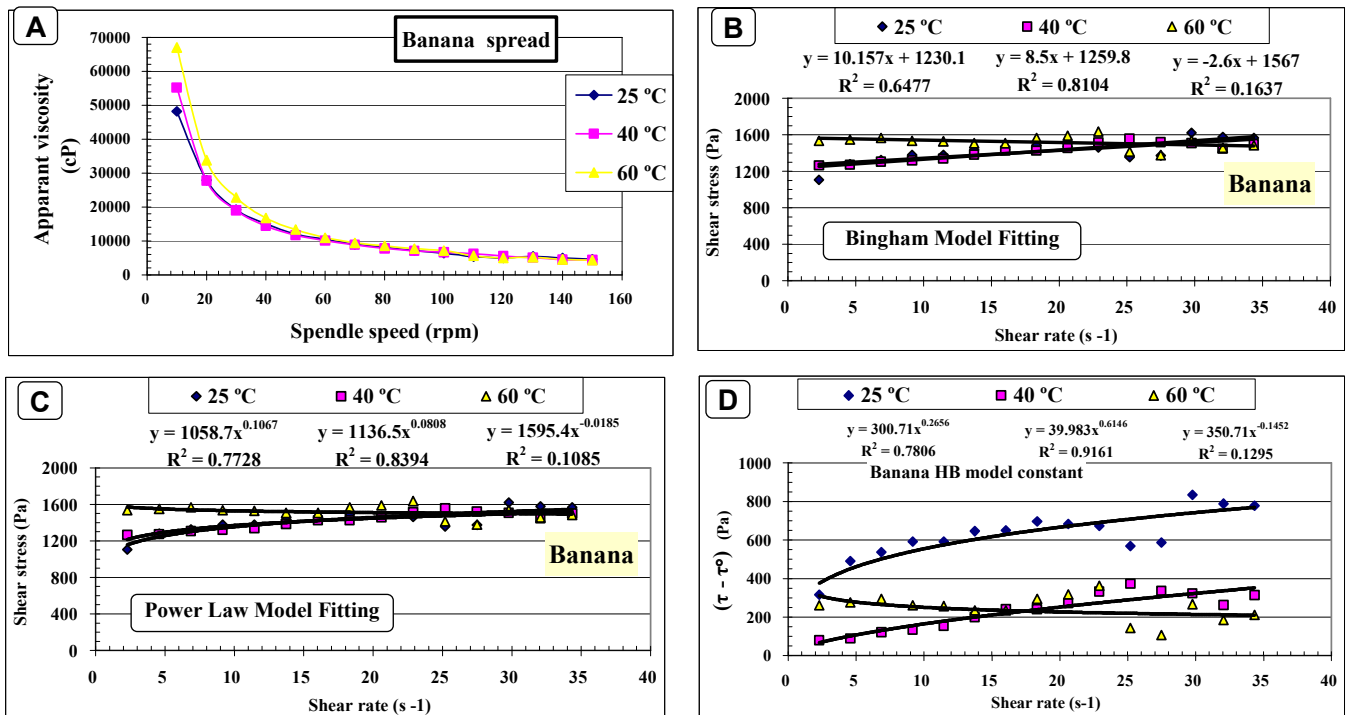


Figure (3). Rheological data of banana spread and model constants calculations (B; Bingham; C Power law; D; Herschel-Bulkley models).



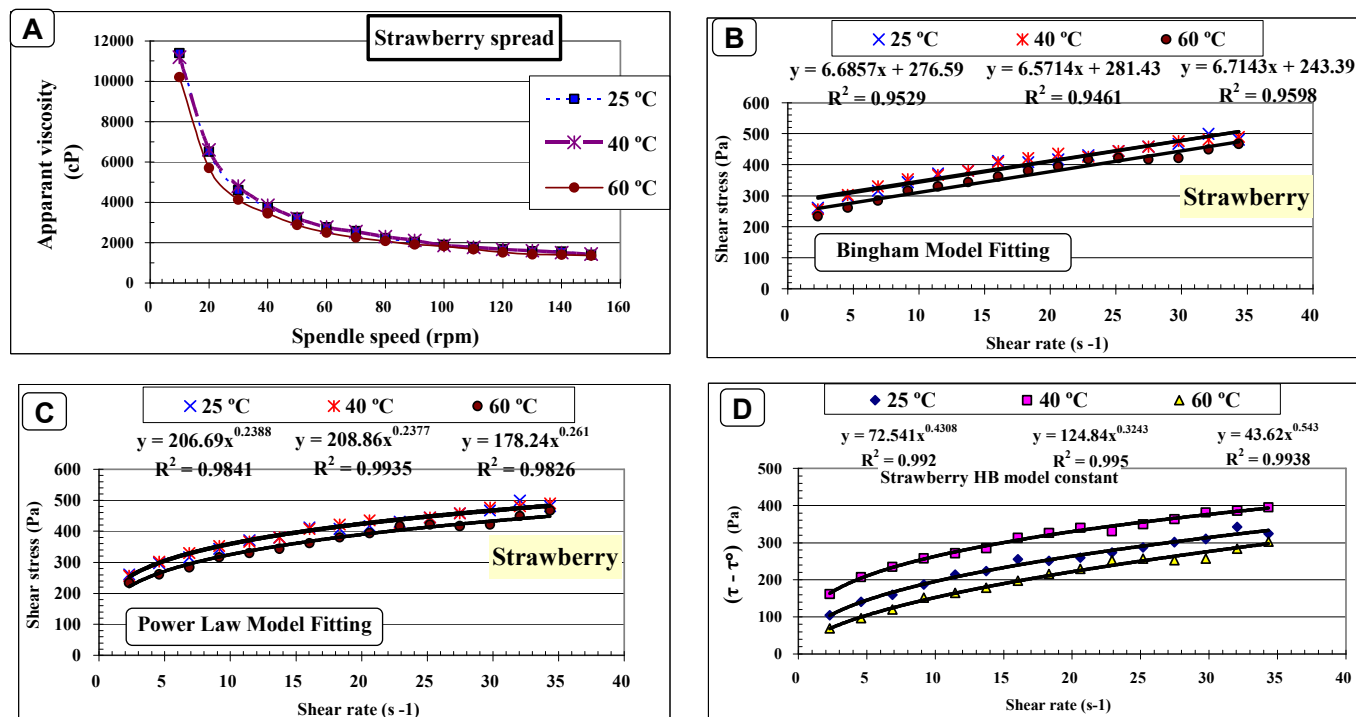


Figure (4). Rheological data of strawberry spread and model constants calculations (B; Bingham; C Power law; D; Herschel-Bulkley models).

Table (2). Parameters and  $R^2$  of different rheological models fitted to the data of some fruit spreads and guava puree.

Product		Guava puree		Guava spread			Banana spread			Strawberry spread		
Gum (1%)		none	none	CMC	Guar	Xanthan	Xanthan	Xanthan	Xanthan	Xanthan	Xanthan	Xanthan
Models; parameters		40 °C	60 °C	25 °C	25 °C	25 °C	25 °C	40 °C	60 °C	25 °C	40 °C	60 °C
Newtonian	$R^2$	0.857	0.872	0.916	0.902	0.877	0.828	0.808	0.759	0.893	0.891	0.902
	$\mu$	37.75	33.51	48.22	48.34	80.93	62.14	61.74	63.62	18.37	18.46	17.00
	$R^2$	0.735	0.895	0.964	0.987	0.944	0.648	0.810	0.164	0.953	0.946	0.960
Bingham	$\mu$	9.71	9.94	21.44	18.87	24.99	10.16	8.50	-2.60	6.69	6.57	6.71
	$\tau_0$	663.53	557.80	633.70	697.29	1323.88	1230.06	1259.81	1566.97	276.59	281.43	243.39
	$R^2$	0.878	0.977	0.990	0.967	0.946	0.773	0.839	0.108	0.984	0.994	0.983
Power law	$n$	0.18	0.20	0.30	0.25	0.19	0.11	0.08	-0.02	0.24	0.24	0.26
	$K_{PL}$	513.12	429.33	442.36	529.59	1053.06	1058.73	1136.47	1595.35	206.69	208.86	178.24
	$R^2$	0.808	0.950	0.992	0.994	0.966	0.710	0.857	0.140	0.984	0.982	0.987
Casson	$K_C$	1.41	1.50	2.72	2.30	2.35	1.11	0.90	-0.24	1.35	1.33	1.41
	$\sqrt{-\tau_0}$	23.19	21.00	20.74	22.77	32.51	33.07	33.93	39.95	14.39	14.53	13.28
	$R^2$	0.8785	0.9768	0.9976	0.9954	0.9675	0.7806	0.9161	0.1295	0.992	0.995	0.9938
Herschel-Bulkley	$\tau_0$	159.3	64.5	369.3	583.2	1142.5	787.4	1184.1	1272.1	156.8	94.8	164.4
	$n$	0.229	0.2195	0.531	0.6886	0.6697	0.2656	0.6146	-0.1453	0.4308	0.3243	0.543
	$K_{HB}$	362.77	369.33	147.03	64.48	94.63	300.71	39.98	350.71	72.54	124.88	43.62

$R^2$  = Regression coefficient;  $\mu$  = apparent viscosity;  $\tau_0$  = yield stress;  $K$  = consistency coefficient;  $n$  = the flow behavior index.

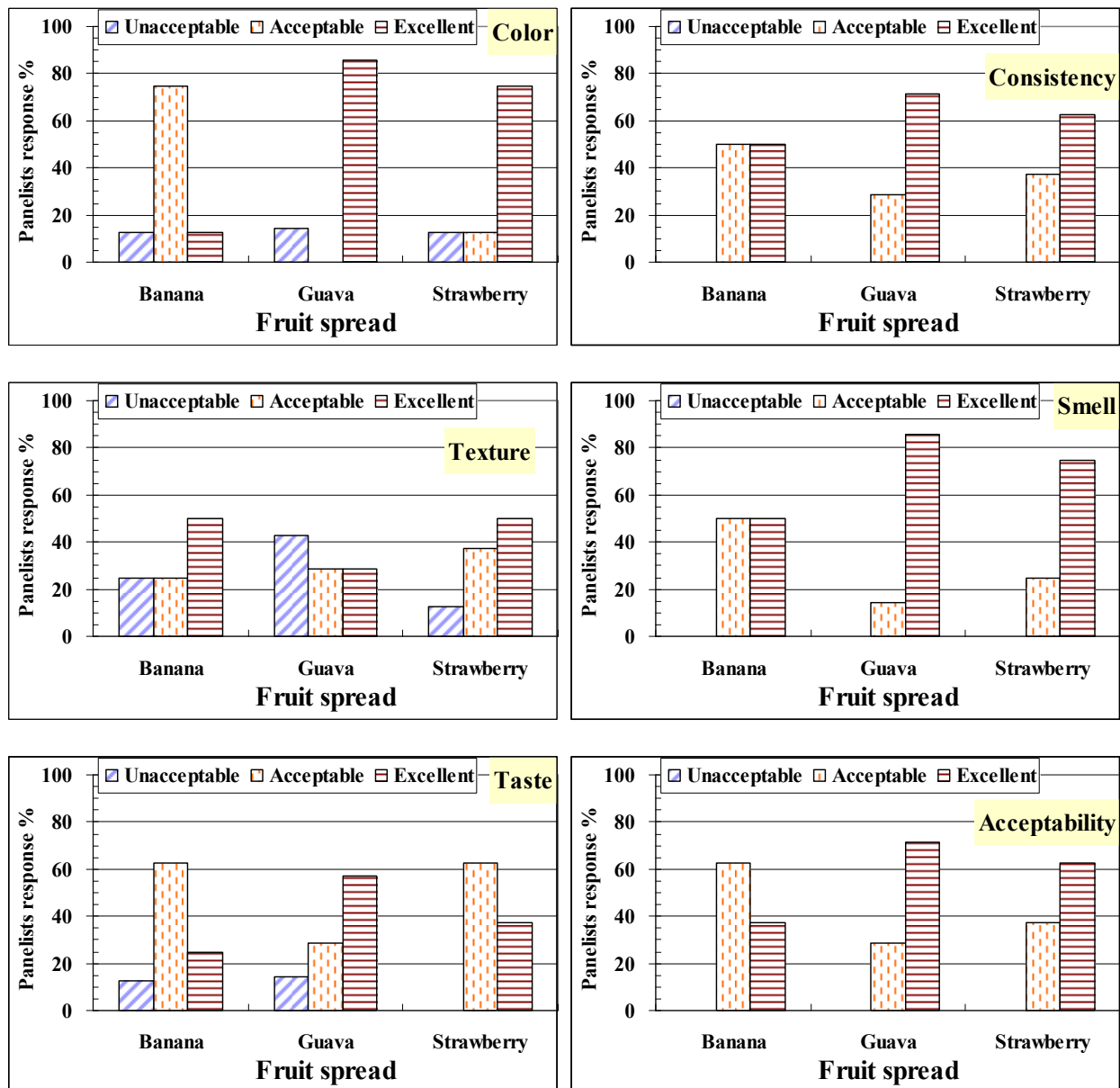


Figure (5). Percentage of panelists response to sensory attributes of the three fruit spreads.

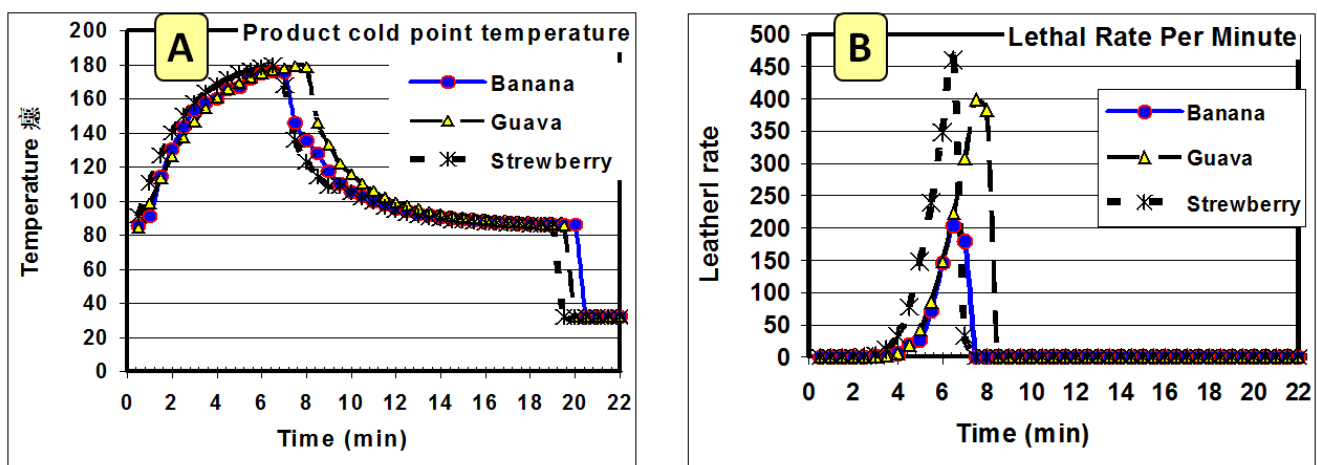


Figure 6. A). Heat penetration curves of banana, guava and strawberry spreads (1% xanthan gum) packaged in PA/PE flexible packages. B). Lethality curves at the coldest point of banana, guava and strawberry spreads (1% xanthan gum) packaged in PA/PE flexible packages.



## 4. Conclusion

Fruit spreads, at 1% gum concentration, exhibited shear thinning pseudoplastic non-Newtonian properties. Herschel-bulkley and Power law models fitted well to the rheological data, followed by Casson model. These results were in agreement with those reported by Guerrero and Alzamora, (1997), Ditchfield, et al., (2004), Ahmed J., (2007) and Alvarez, and Canet, (2013).

The heat penetration profile suggested possible use of flexible pouches for packaging fruit spread. The sensory evaluation of guava, banana and strawberry spreads indicated acceptable products by the panelists for most evaluated attributes. Further work should be directed towards production at a pilot plant scale and study the shelf life of the product.

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