เทคโนโลยีการปรับเนื้อสัมผัสด้วยรีโอโลยี: ซอสพริก (กรณีศึกษา)

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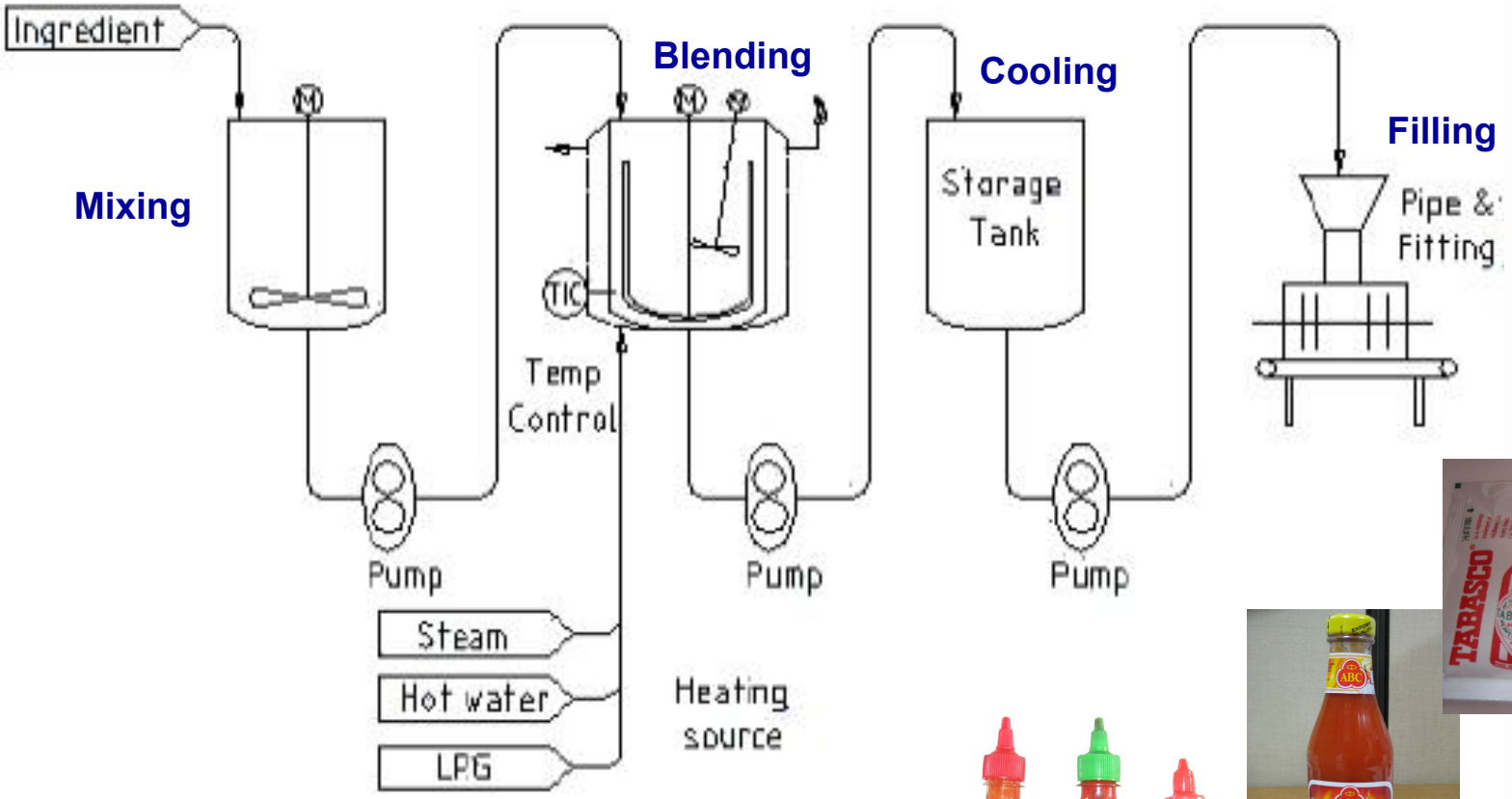
Chili (Capsicum sp.)

- Industrial crop widely cultivated in Thailand (> 500,000 rai and produce > 500 tonnes yearly)
- Two groups (i) Hot/Spicy chili and (ii) Sweet pepper
- Contain capsaicin (bioactive compound), high vitamins A & C (ascorbic acid) ➔ health benefits
- Raw materials for food processing, food preservation for value additions e.g. dried chili, chili paste, chili sauces

Chili Sauces

- widely consumed in Thailand and Asia (yearly export value > one billion bahts)
- add piquant taste to their accompanying dishes
- typical ingredients include: fresh/processed chili, water, garlic, sugar, salt, vinegar and thickening agent

Processing Chili Sauces



- Shear rate range: 10^{-3} – 10^{3} /s

Factors to consider in making sauce

- **Rheological behaviour**:
  - If the sauce is to be poured, it should pour!
  - Rheologically stable across processing conditions (large range of shear rate 10^{-3}-10^{3} s^{-1} e.g. sedimentation, pouring, swallowing, mixing etc.)
- **Texture**: Should it be smooth or lumpy?
- **Stability (shelf life)**: Does it need a thickening agent?
- **Appearance**: Should make it look appetising and pour or coat according to its purpose to give your meals that extra something!!!

How to adjust texture of sauce

- **Types of hydrocolloid**

  e.g. CMC has a lower viscosity compared to guar gum and xanthan gum

- **Hydrocolloid concentration**

  e.g. an increase in concentration causes a higher viscosity and consistency

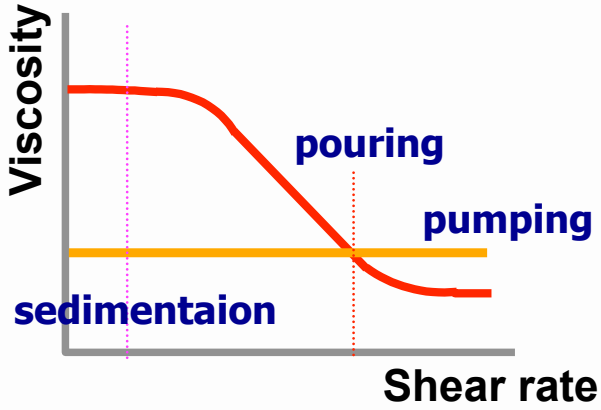
- **Sauce formulation**

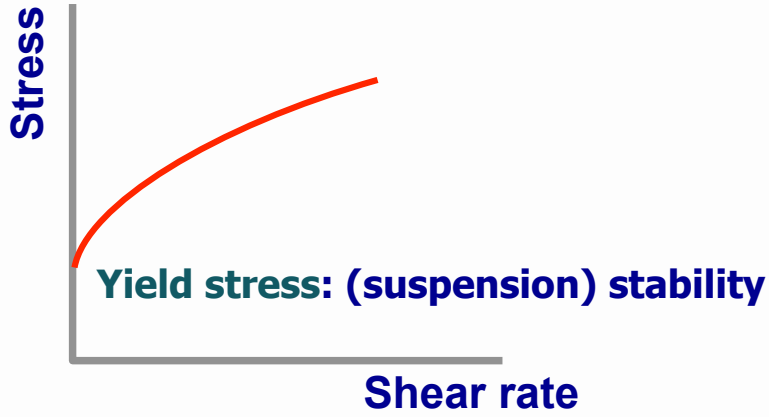
  e.g. a higher TSC in sauce, a higher viscosity and consistency

Food Rheology

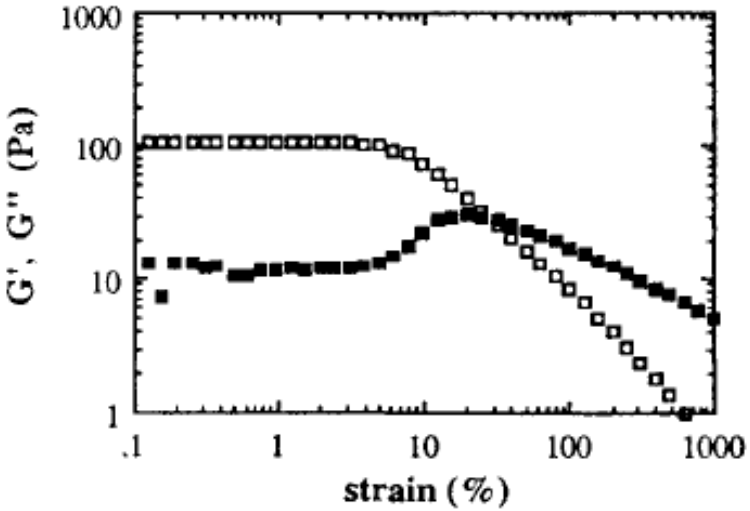
Chili sauces: suspension system

- Viscosity

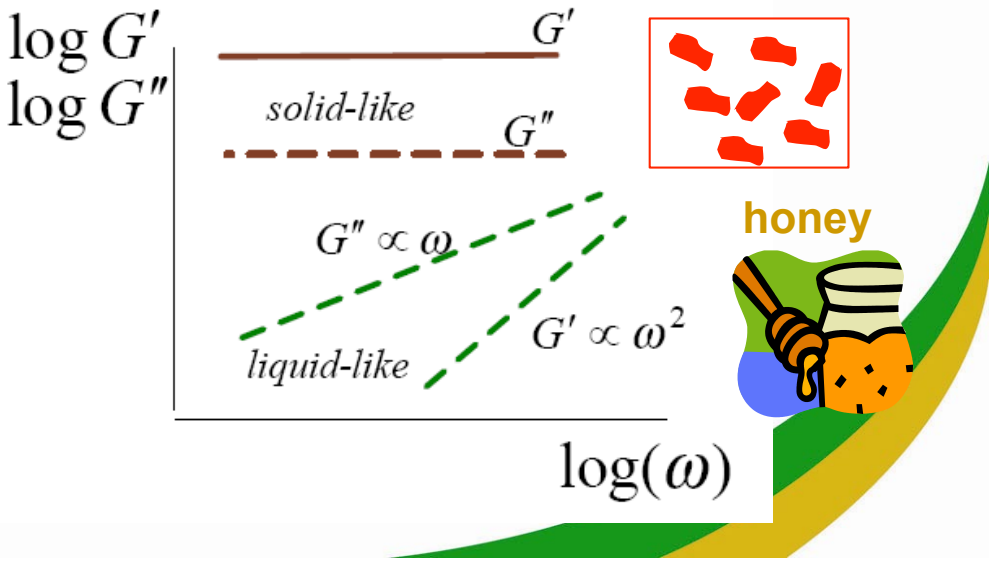




- Critical stress: stress sweep



- Viscoelasticity: freq sweep



Scope of Research

- To study the chemical, physical and rheological properties of four commercial chili sauces (here called F, H, K and A)
- To investigate the type of hydrocolloids used in the production of chili sauce
- To develop a lab-scale chilli sauce with comparable rheological property as a commercial product

Commercial Sauce Samples

Ingredients	F	H	K	A
Chili	28	28	60 (fermented)	N/A
Sugar	17	23	10	N/A
Vinegar	16	10	5	N/A
Garlic	12	9.5	25	N/A
Salt	10	-	-	N/A
Preservation/Colour	Yes	No	No	N/A
Total**(% w/w)	83	70.5	100	N/A

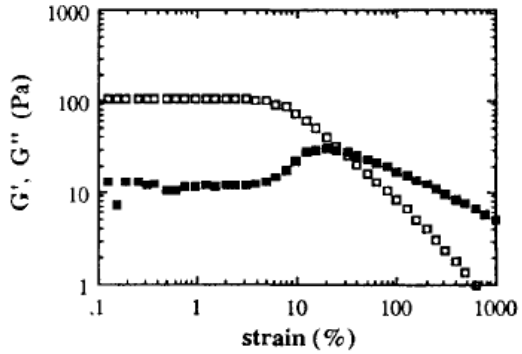
* N/A means data are not available from the sauce label
** Missing ingredients include water, MSG and hydrocolloid

Experimental Methods

- Determination of Physical and Chemical Properties
  - pH, total solid content (TSC) and colour
- Optical Microstructural Analysis
  - Sizes of chili particles and oil droplets
- Determination of hydrocolloid types used in commercial chili sauces
  - FTIR and colour staining techniques

Rheological Experiments

- Stress sweep experiment
  - to determine a linear viscoelastic region
  - performed at 0.1-100 Pa at fixed frequency of 1 Hz



- Frequency sweep experiment
  - to determine viscoelastic property e.g. solid-like or liquid like
  - performed at fixed stress of 1 Pa (within linear viscoelastic region)

    frequency range of 0.01-50 Hz
- Steady shear experiment
  - shear rate of 0.0003-100 s^{-1}
  - data are fitted with the Herschel-Bulkley model ➡ $\sigma = \sigma_0 + K\dot{\gamma}^n$

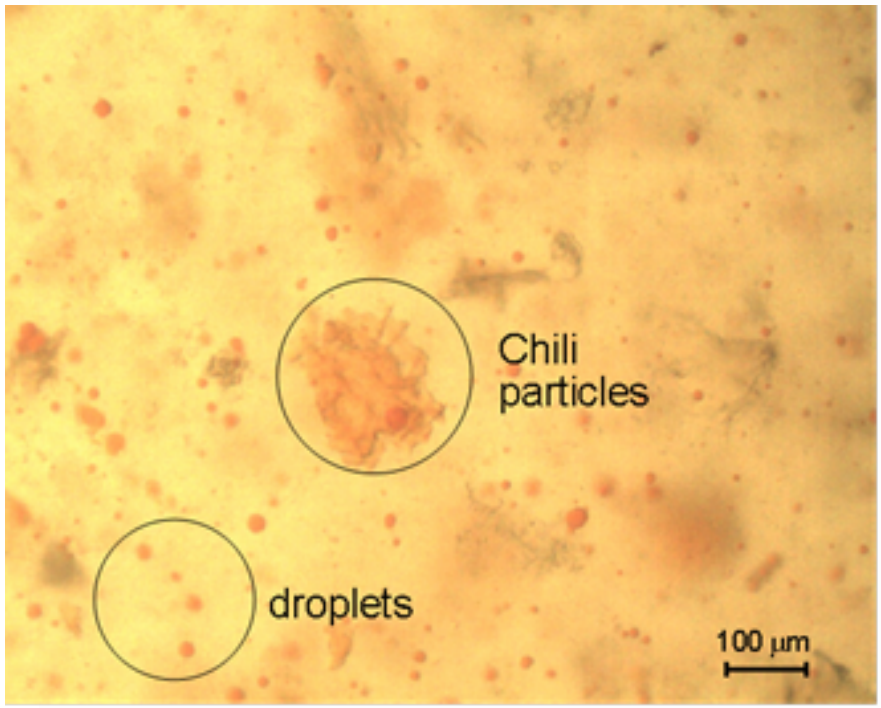
  to obtain the consistency (K) and flow behaviour (n) indices

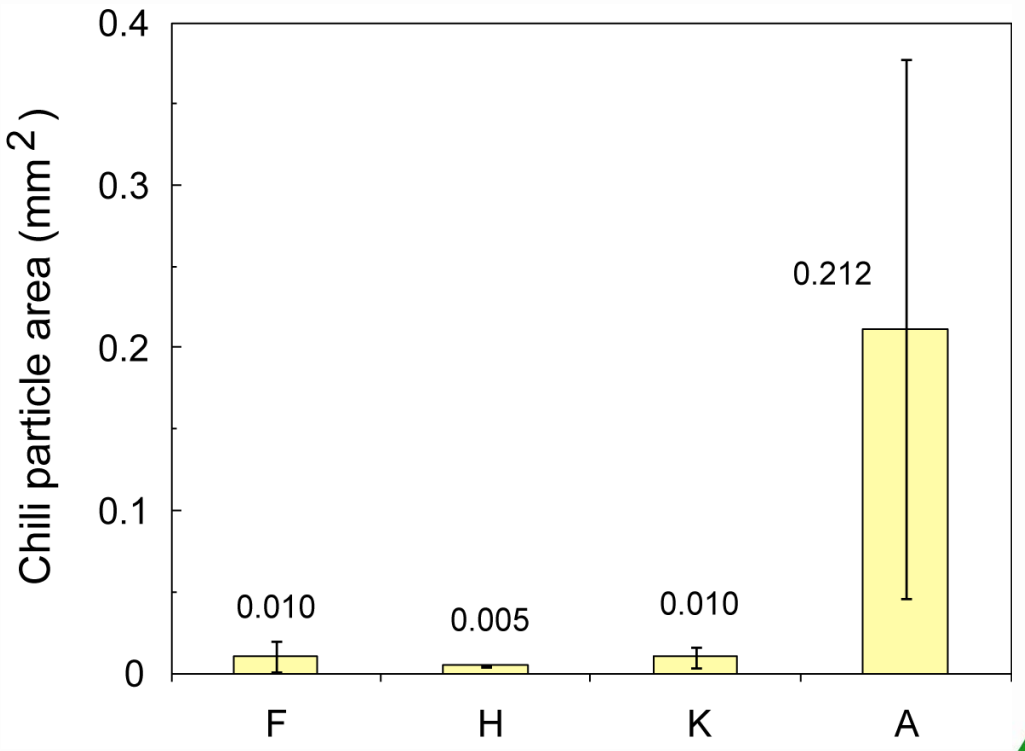
Physical and Chemical Properties

Sauces	pH	L*	a*	b*	TSC
F	3.43 ± 0.09^{c}	33.83 ± 0.04^{a}	23.87 ± 0.07^{a}	27.72 ± 0.10^{a}	17.04 ± 0.06^{d}
H	3.56 ± 0.12^{b}	29.52 ± 0.71^{c}	18.06 ± 0.48^{c}	23.34 ± 1.01^{b}	30.07 ± 0.63^{c}
K	3.51 ± 0.06^{bc}	29.33 ± 0.16^{c}	19.17 ± 0.13^{b}	22.80 ± 0.20^{cb}	30.72 ± 0.11^{b}
A	4.09 ± 0.01^{a}	30.63 ± 0.27^{b}	24.65 ± 1.00^{a}	22.86 ± 0.63^{cb}	39.33 ± 0.01^{a}

$^{a\text{-}f}$ means with different superscripts in the same column are significantly different

Optical Microstructure Analyses





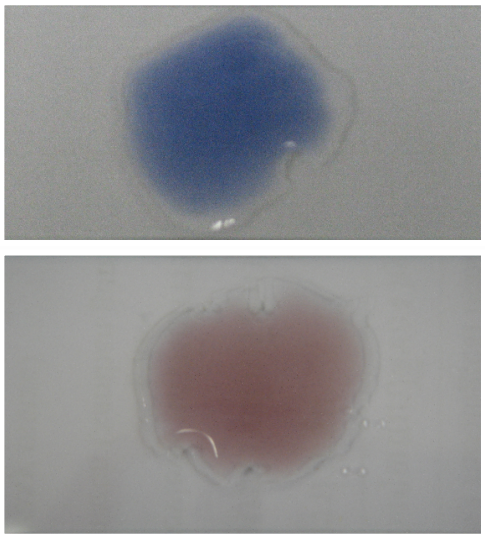
Grainiest texture: A > K, F > H

FTIR Characteristics

FTIR spectra characteristics of hydrocolloids extracted from various chili sauces, native or crosslinked tapioca starches, xanthan gum, guar gum and carboxymethyl cellulose.

Wavenumber (cm^{-1})						Band assignment
Hydrocolloids from sauce F	Hydrocolloids from sauce A, H, and K	Native or Crosslinked tapioca starches	Xanthan gum	Guar gum	CMC	
3366	3350–3375	3322	3298	3320	3273	OH stretching
2929	2930–2933	2932	2913	2926	2921	CH stretching
	1732–1742		1731			C=O stretching (ester)
1641	1643–1653	1650		1658		Water associated in biopolymers
			1614		1598	COO^- stretching (asymmetry)
1418	1413–1426	1421	1424	1424	1426	CH_2 in pyranose ring bending
					1377	COO^- stretching (symmetry)
					1330	C–O stretching
1241	1241–1243	1244	1257		1267	O–H bending
1152	1154–1157	1157	1155	1152	1155	C–O–C asymmetric stretching
1076	1079–1080	1080	1052	1076	1062	C–O–C bending (glycosidic linkage)
1020	1015–1022	1015	1026	1024	1015	C–O valence vibration
928	929–934	928			911	Pyranose ring vibration
			895	869	897	β-conformer
855	858–861	858				α-conformer
				815		Characteristic peak of guar gum

Detection of Hydrocolloids



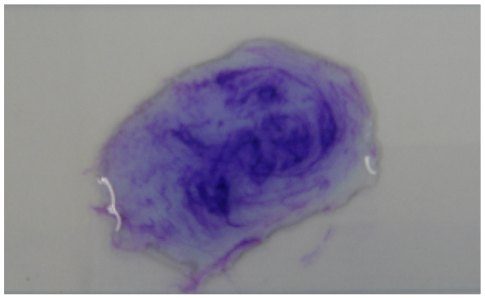
Starch: stain with **1% Lugol**

Yellow ⇨ Blue

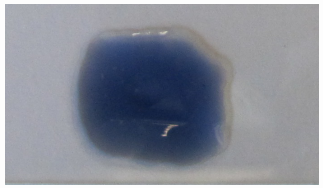
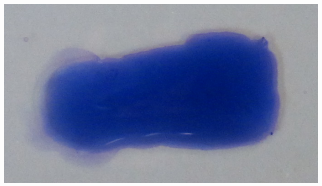
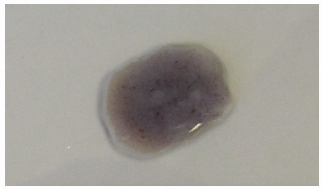
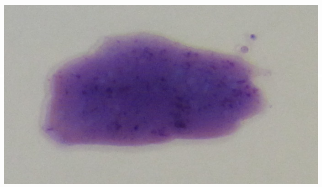
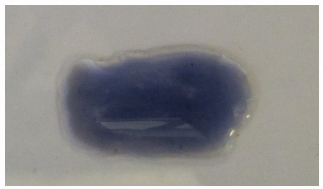
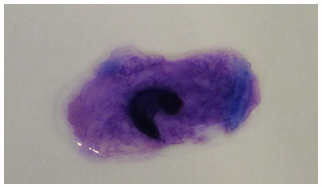
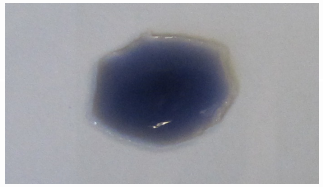
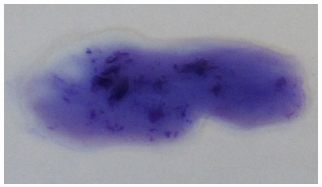
Yellow ⇨ Red/Brown (Low amylose e.g. waxy starch)

Xanthan: stain with **0.1% Toluidine blue**

Dark blue ⇨ Purple



Staining Observations

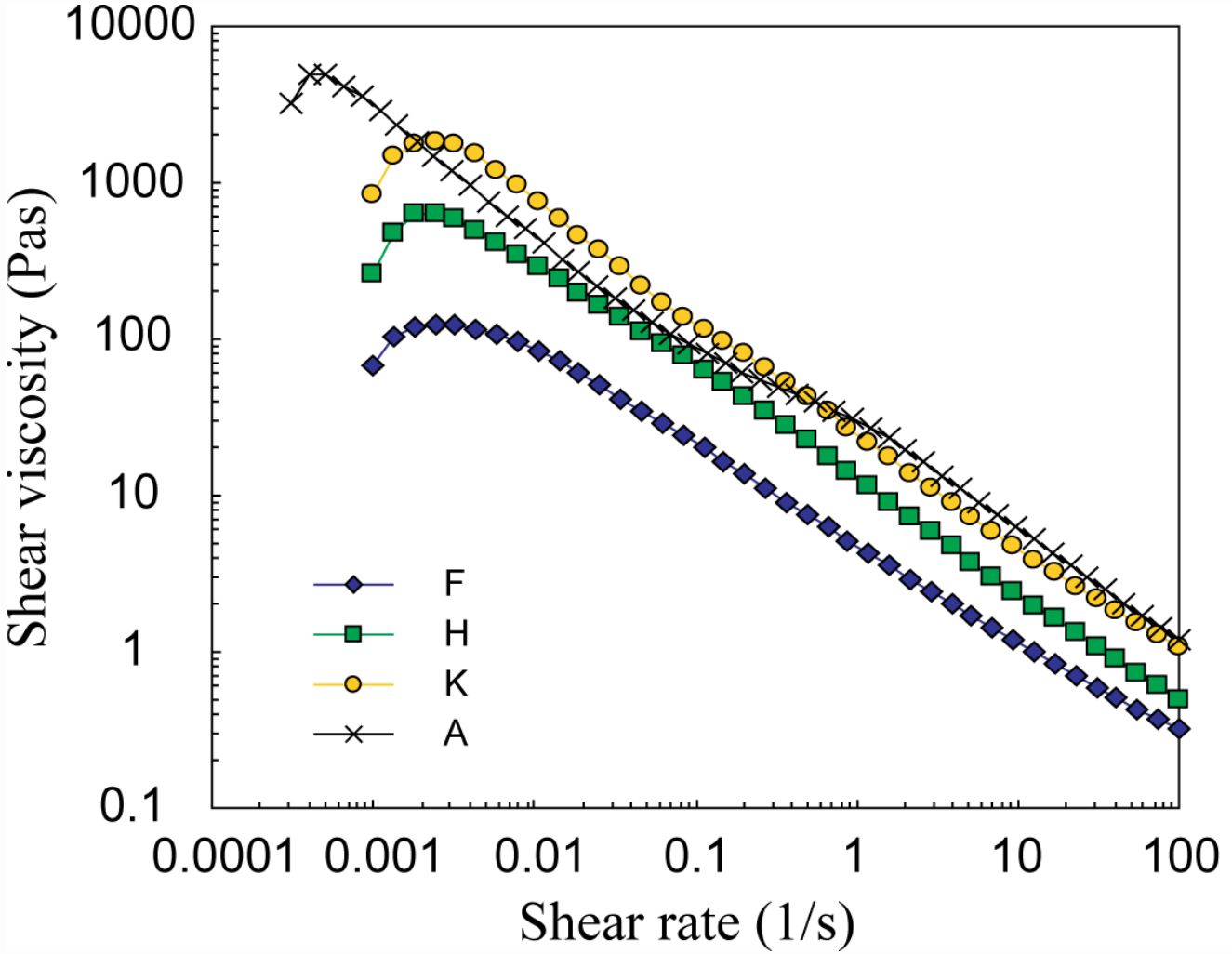
Chili sauce	Starch (1% Lugol)	Xanthan (0.1% Toluidine blue)
F		
K		
H		
A		

Rheological Behaviour of Chili Sauces

Chili Sauces	Stress sweep	Frequency sweep*			
	σ_c (Pa)	G" (Pa)	G' (Pa)	tan(δ)	Remarks
F	0.2	2.6	4.8	0.5	Gel-like
H	0.9	9.5	32.8	0.3	Gel-like
K	1.5	16.0	83.5	0.2	Gel-like
A	1.8	76.0	231.9	0.3	Gel-like

* Values obtained from frequency of 0.1 Hz

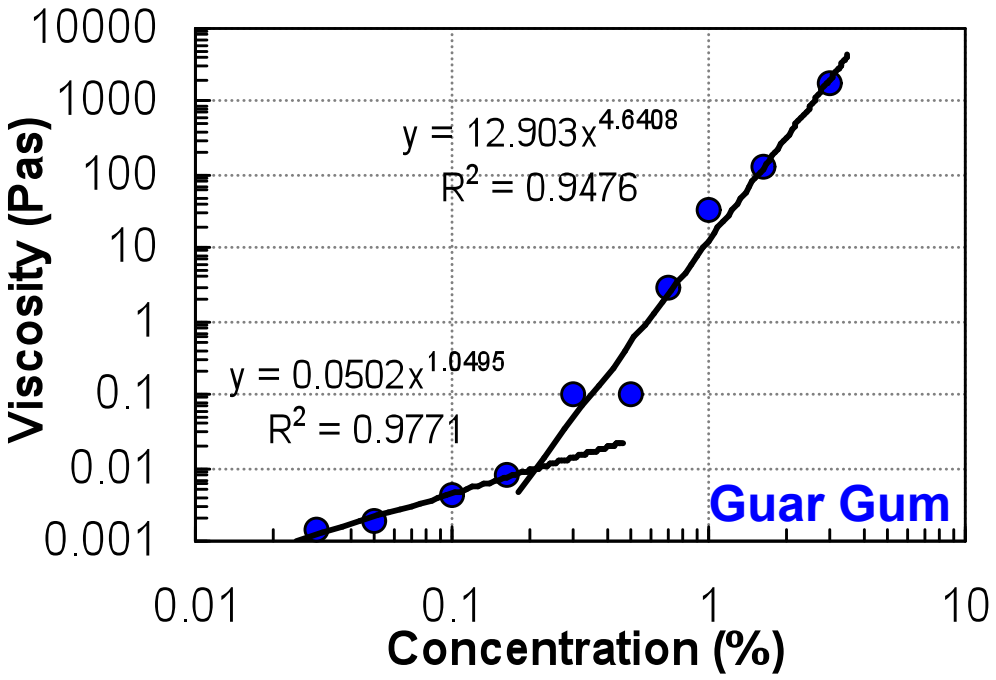
Flow Curves of Commercial Sauces

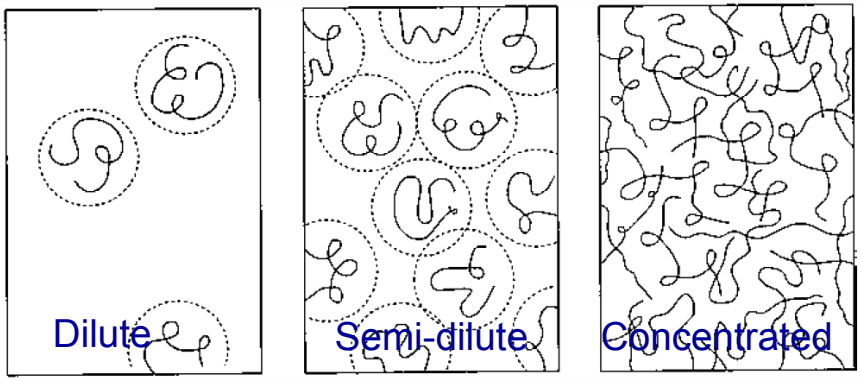


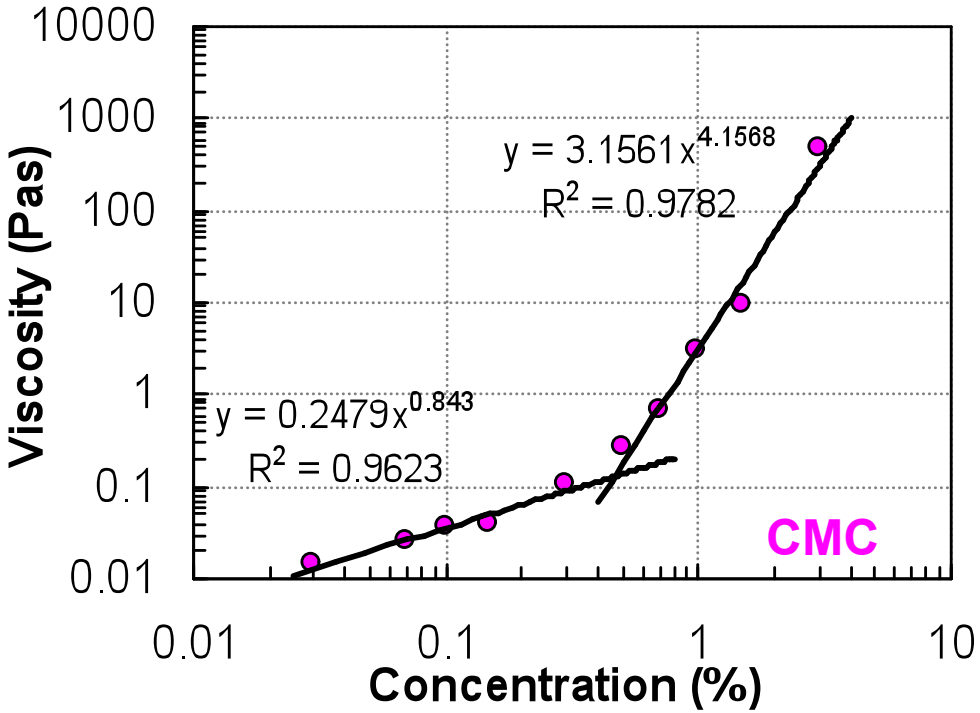
Summary of Sauce Properties

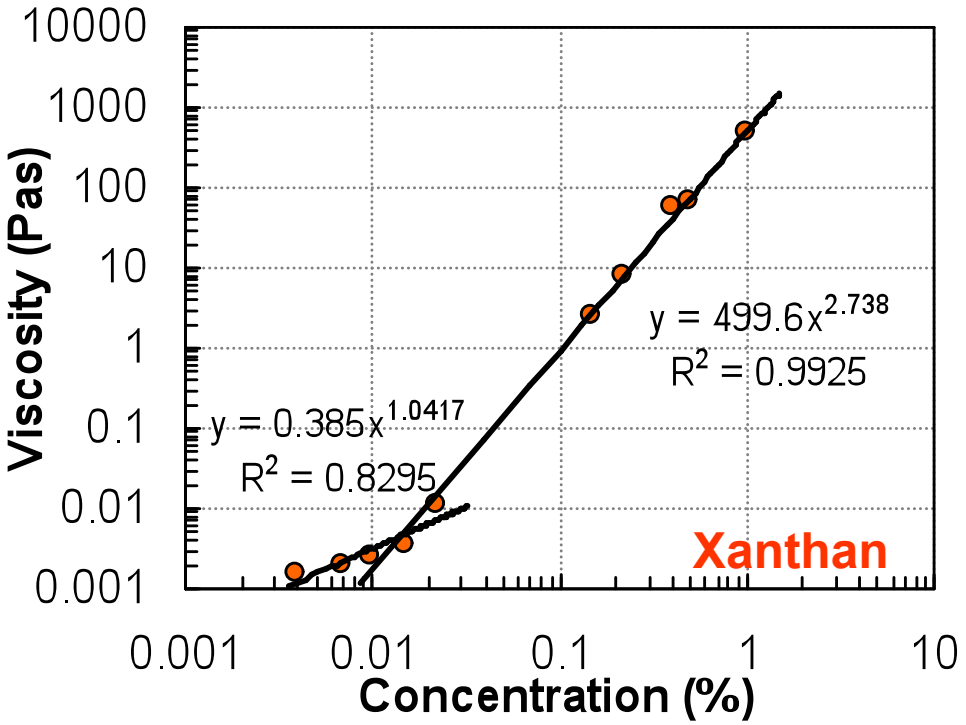
Chili sauces	K (Pas^n)	n	σ_y (Pa)	TSC (%)	Starch	Xanthan
F	4.5	0.41	0	17.04	✓	X
H	10.9	0.32	1.6	30.07	✓	✓
K	19.0	0.35	4.5	30.72	✓ (waxy type)	✓
A	26.2	0.31	2.6	39.33	✓	✓

- Two factors influencing rheological behaviours of chili sauces
  - Total solid content
  - Type of hydrocolloid





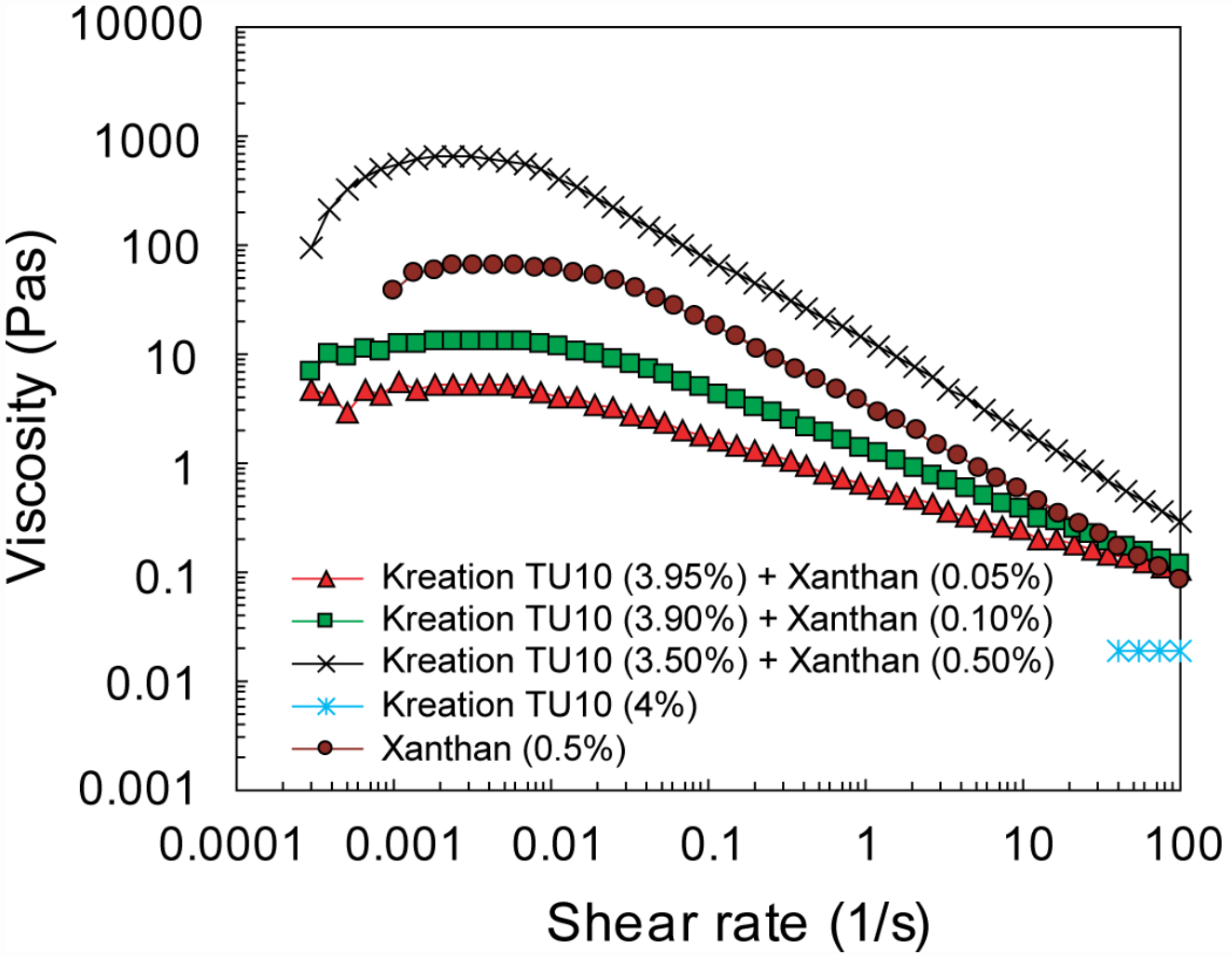




Critical concentration;

Xanthan < Guar Gum < CMC

Flow Curves of Mixed Hydrocolloids



Synergistic Effect: Kreation TU10 (3.5%) + Xanthan (0.5%)

Table I: Properties of modified starch (Kreation TU10)

ρ (g/ml)	Q_e	Q_v
1.51	8.08	13.22

1 ml of Kreation TU10 ⟹ 13.22 (volume swelling)

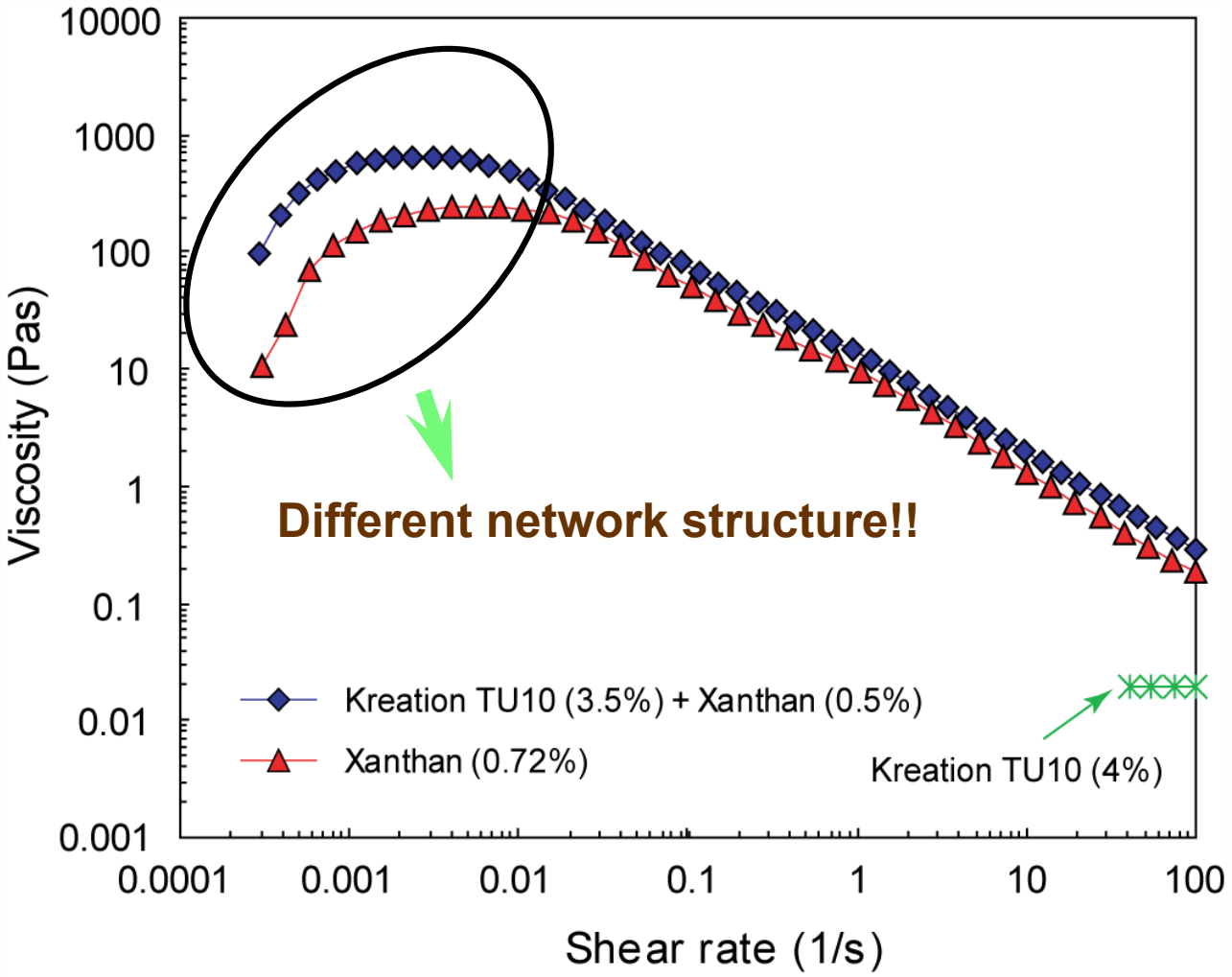
1.51g of Kreation TU10 ⟹ 13.22

$\therefore$ 3.5g of Kreation TU10 ⟹ $\frac{13.22 \times 3.5}{1.51} = 30.64$

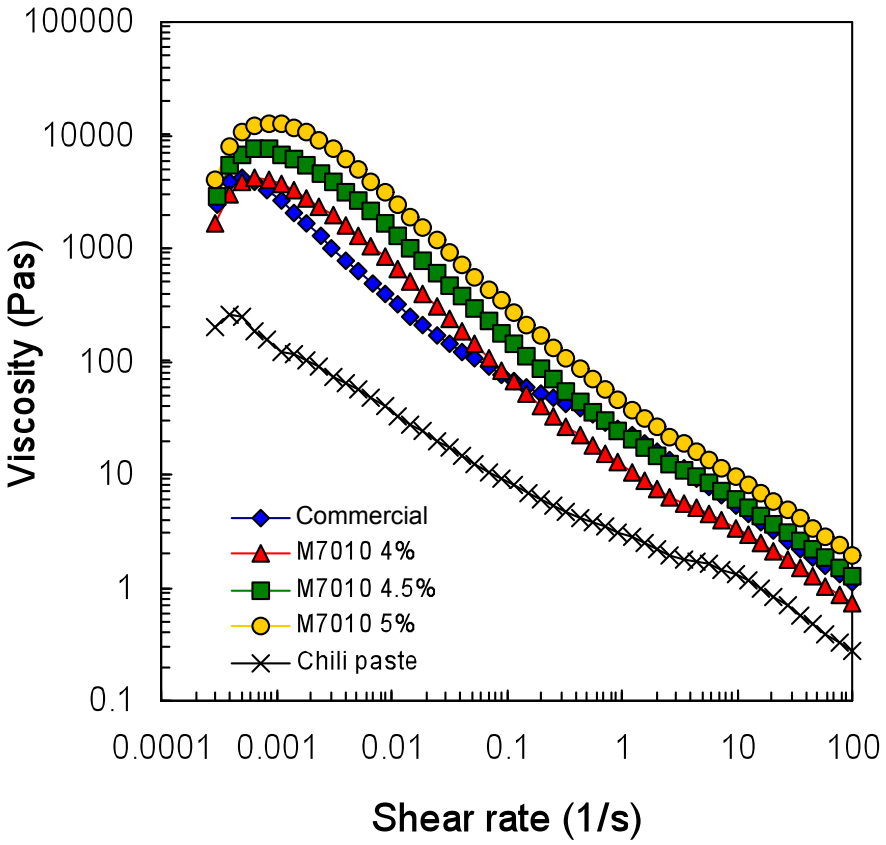
$\therefore$ Water left for Xanthan = 100 – 30.64 = **69.36 ml**

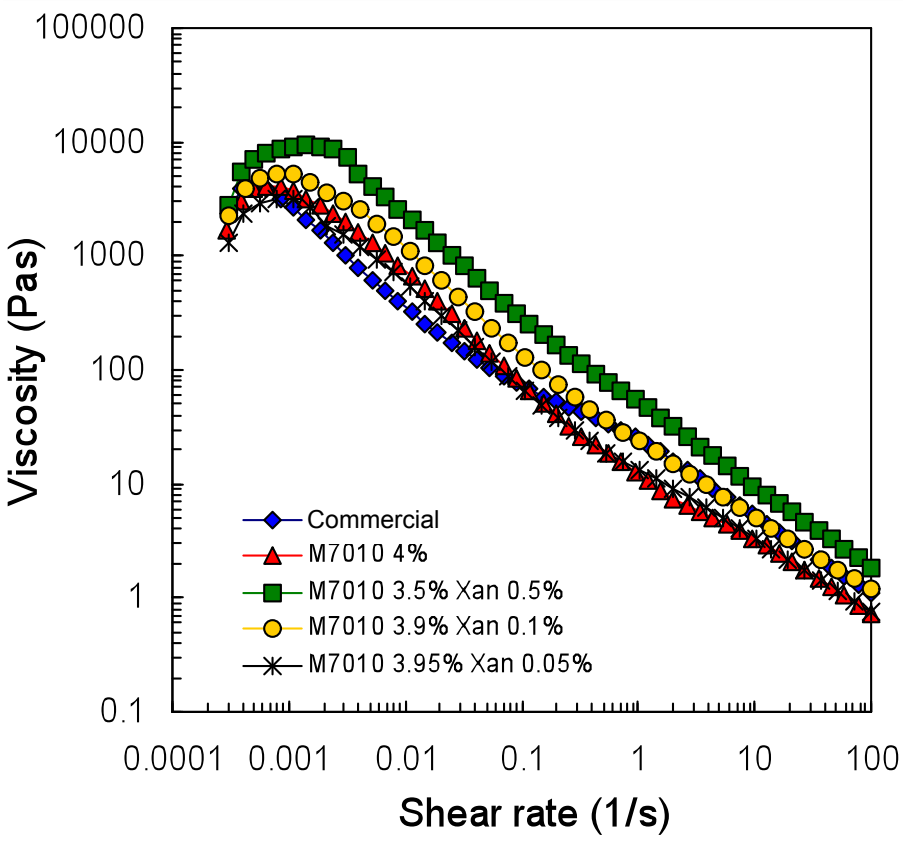
Actual xanthan concentration = $\frac{0.5}{69.36} \times 100 = 0.72\%$

Synergistic Effect: Kreation TU10 and Xanthan



Lab-scale Chili Sauces





Flow Properties of Lab-scale Sauces

Chili sauce system	Viscometry test		
	σ_y (Pa)	*K*	*n*
Commercial	2.2	20.5	0.4
M7010 (4%)	2.7	12.4	0.4
M7010 (4.5%)	6.4	24.3	0.3
M7010 (5%)	10.8	38.2	0.3
M7010 (3.5%) + Xanthan (0.5%)	13.2	38.2	0.3
M7010 (3.9%) + Xanthan (0.1%)	5.9	18.4	0.4
M7010 (3.95%) + Xanthan (0.05%)	2.5	12.9	0.4

Summary

- Most commercial chili sauces usually consist of starch and/or xanthan in their ingredients. These hydrocolloids are added for thickening and stabilising suspensions purposes.
- All studied chili sauces have a non-Newtonian and pseudoplastic behaviour, i.e. shear-thinning fluids. Flow behaviours are affected by TSC and type of hydrocolloid added to the sauce ingredient.
- Rheological tests revealed that there was a synergy between Kreation TU10 and xanthan within the mixture of Kreation TU10 (3.5%) and xanthan (0.5%) suspension. However, the synergistic mechanism between these hydrocolloids was not fully understood.
- More information can be found in Gamonpilas et al. (2011) *Physicochemical and rheological characteristics of commercial chili sauces as thickened by modified starch or modified starch/xanthan mixture*, J. Food Eng 105, 233-240.

Acknowledgement

- Funding from Siam Modified Starch, Co., Ltd., Thailand