Food Hydrocolloids

Food formulation course

Dr Ali Nasirpour

Table 1.1 Source of commercially important hydrocolloids

Botanical		
	trees	
		cellulose
	tree gum exudates	
		gum arabic, gum karaya, gum ghatti, gum tragacanth
	plants	
		starch, pectin, cellulose
	seeds	
		guar gum, locust bean gum, tara gum, tamarind gum
	tubers	
		konjac mannan
Algal		
	red seaweeds	
		agar, carrageenan
	brown seaweeds	
		alginate
Microbial		
		xanthan gum, curdlan, dextran, gellan gum, cellulose
Animal		
		Gelatin, caseinate, whey protein, chitosan

Table 1.2 Price of the major hydrocolloids

Hydrocolloid	Principal function	Cost $/kg in 1983*	Cost $/kg in 1993**	Cost $/kg in 1999***
Agar	Gelling agent	15.0–15.4	19.72	
Alginate	Gelling agent	7.7–9.9	6.58	
Arabic	Emulsifier	2.64	3.69	
Carrageenan	Gelling agent	5.5–13.2	7.35	8–17.6
Processed euchema seaweed	Gelling agent			8
Carboxymethyl cellulose	Thickener	3.5–4.4	3.18	4.8–8
Hydroxypropyl cellulose	Thickener and emulsifier	6.6–8.3		
Methyl cellulose	Thickener, emulsifier and gelling agent	6.6		9.6–11.2
Microcrystalline cellulose	Thickener and gelling agent	3.9–4.3		
Gelatin	Gelling agent	4.4	4.04	5.72–9.02
Guar gum	Thickener	1.0–1.1	0.77	2.86
Karaya	Thickener	4.6	2.89	
Locust bean gum	Thickener	4.6	6.40	
Pectin	Gelling agent	7.6	9.19	11.2–16
Pectin (low methoxy)	Gelling agent	10.6		
Propylene glycol alginate	Emulsifier and foam stabiliser	9.1		
Starch	Thickener and gelling agent	0.5		
Starch (modified)	Thickener and gelling agent	1.3		
Tragacanth	Thickener	26.4–35.2	9.60	
Xanthan gum	Thickener	13.4		13.64

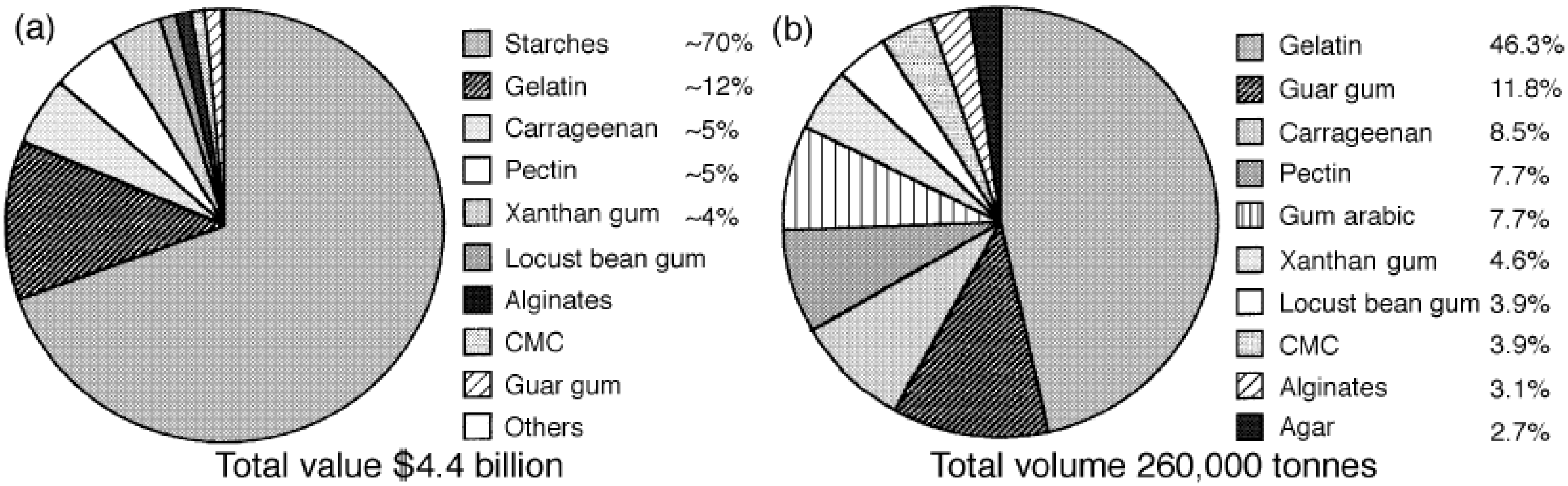

Fig. 1.2 (a) Value of world market for individual hydrocolloids. (b) Volume of world market for individual hydrocolloids.

Table 1.5 Main hydrocolloid thickeners

Xanthan gum Very high low-shear viscosity (yield stress), highly shear thinning, maintains viscosity in the presence of electrolyte, over a broad pH range and at high temperatures.
Carboxymethyl cellulose High viscosity but reduced by the addition of electrolyte and at low pH.
Methyl cellulose and hydroxypropyl methyl cellulose Viscosity increases with temperature (gelation may occur) not influenced by the addition of electrolytes or pH.
Galactomannans (guar and locust bean gum) Very high low-shear viscosity and strongly shear thinning. Not influenced by the presence of electrolyte but can degrade and lose viscosity at high and low pH and when subjected to high temperatures.

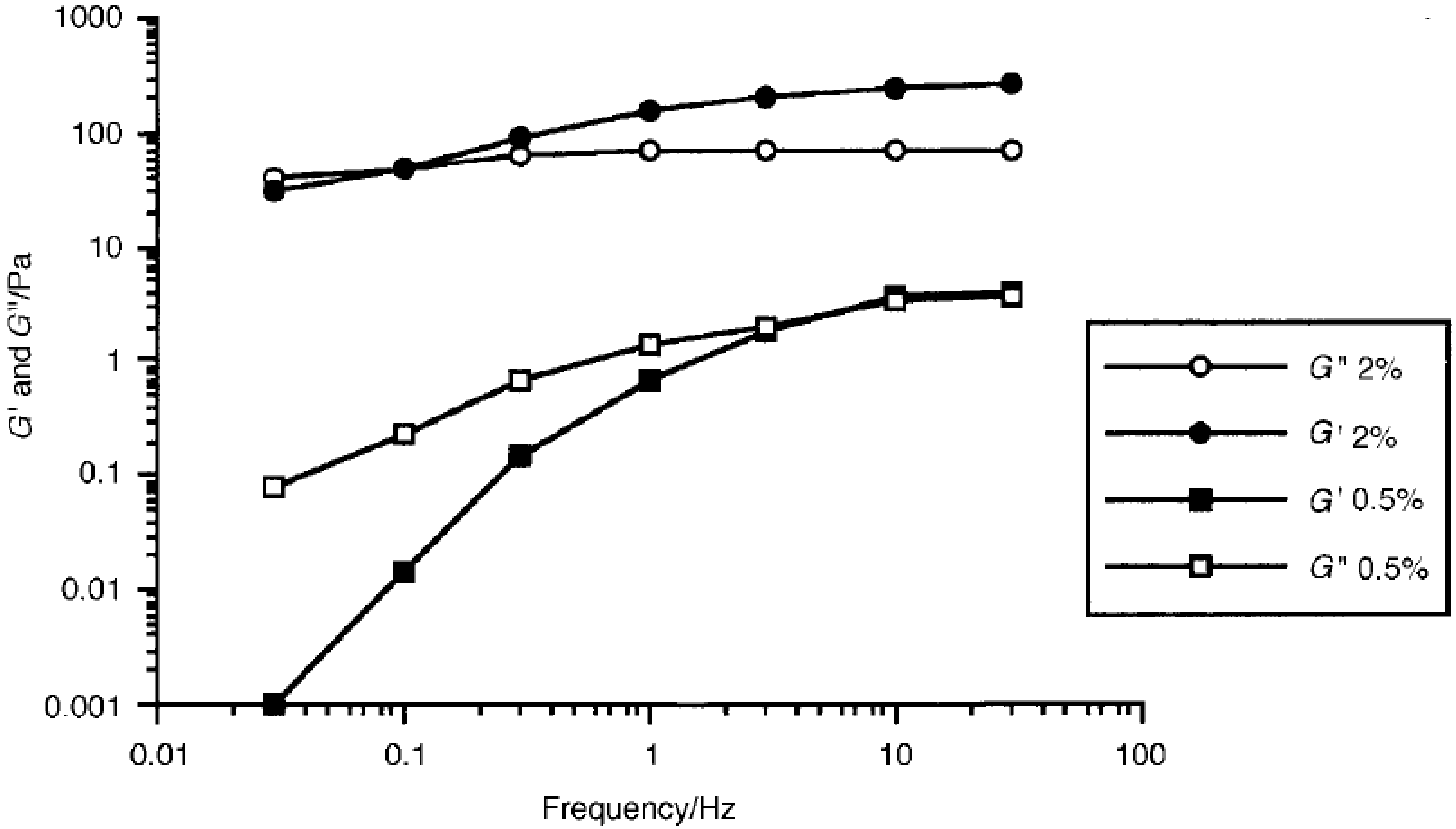

Fig. 1.7 G' and G'' of 0.5% and 2.0% guar gum solutions as a function of frequency.

Table 1.6 Main hydrocolloid gelling agents

1. Thermoreversible gelling agents

Gelatin
Gel formed on cooling. Molecules undergo a coil-helix transition followed by aggregation of helices.

Agar
Gel formed on cooling. Molecules undergo a coil-helix transition followed by aggregation of helices.

***Kappa* Carrageenan**
Gel formed on cooling in the presence of salts notably potassium salts. Molecules undergo a coil-helix transition followed by aggregation of helices. Potassium ions bind specifically to the helices. Salts present reduce electrostatic repulsion between chains promoting aggregation.

***Iota* Carrageenan**
Gel formed on cooling in the presence of salts. Molecules undergo a coil-helix transition followed by aggregation of helices. Salts present reduce electrostatic repulsion between chains promoting aggregation.

Low methoxyl (LM) pectin
Gels formed in the presence of divalent cations, notably calcium at low pH (3–4.5). Molecules crosslinked by the cations. The low pH reduces intermolecular electrostatic repulsions.

Gellan gum
Gels formed on cooling in the presence of salts. Molecules undergo a coil-helix transition followed by aggregation of helices. Salts reduce electrostatic repulsions between chains and promote aggregation. Multivalent ions can act by crosslinking chains. Low acyl gellan gels are thermoreversible at low salt concentrations but non-thermoreversible at higher salt contents ($>$ 100mM) particularly in the presence of divalent cations.

Methyl cellulose and hydroxypropyl methyl cellulose
Gels formed on heating. Molecules associate on heating due to hydrophobic interaction of methyl groups.

Xanthan gum and locust bean gum or konjac mannan
Gels formed on cooling mixtures. Xanthan and polymannan chains associate following the xanthan coil-helix transition. For locust bean gum the galactose deficient regions are involved in the association.

2. Thermally irreversible gelling agents

Alginate
Gels formed on the addition of polyvalent cations notably calcium or at low pH (< 4). Molecules crosslinked by the polyvalent ions. Guluronic acid residues give a buckled conformation providing an effective binding site for the cations (egg box model).

High methoxyl (HM) pectin
Gels formed at high soluble solids (e.g. 50% sugar) content at low pH < 3.5. The high sugar content and low pH reduce electrostatic repulsions between chains. Chain association also encouraged by reduced water activity.

Konjac mannan
Gels formed on addition of alkali. Alkali removes acetyl groups along the polymer chain and chain association occurs.

Locust bean gum
Gels formed after freezing. Galactose deficient regions associate.

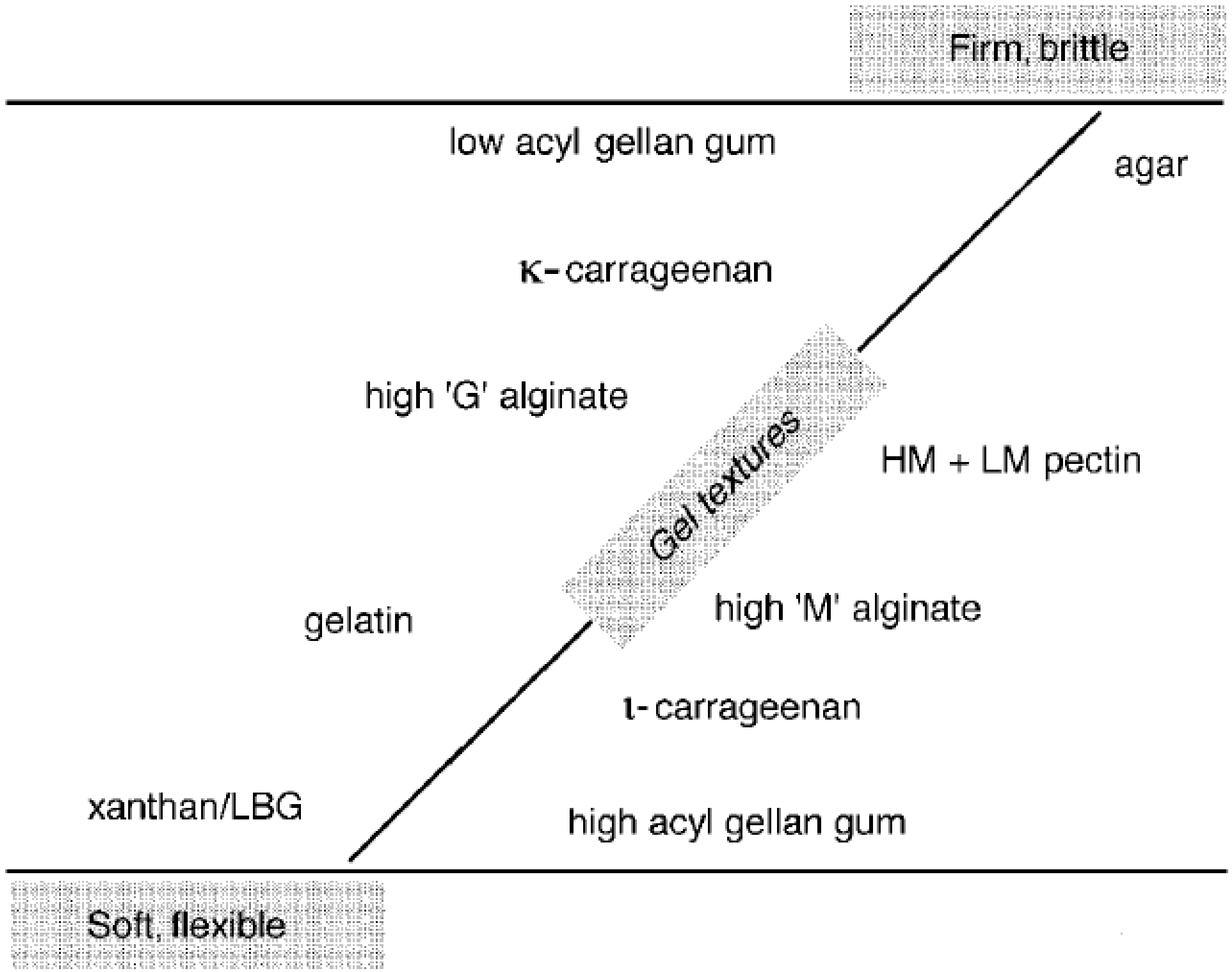

Fig. 1.9 Qualitative comparison of the textures of gels produced by different hydrocolloids.

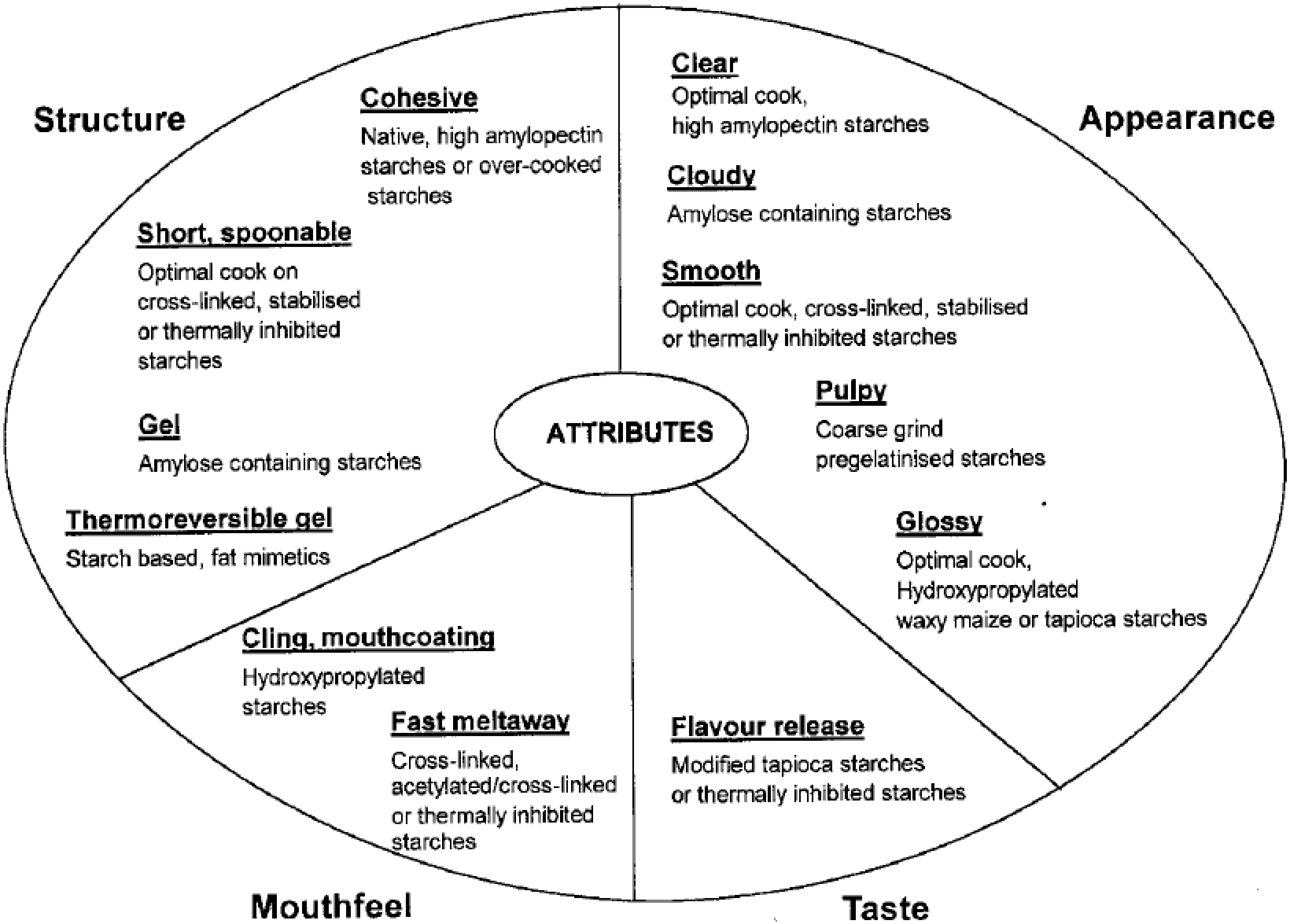

Fig. 3.5 Starch sensory attributes.

Table 3.5 List of food starches permitted under European Food Law

Starch	E Number classification	Classified as	Food product label
Physically modified	–	Ingredient	Starch
Enzymatically modified	–	Ingredient	Starch
Dextrinised	–	Ingredient	Dextrin or modified starch
Acid treated	–	Ingredient	Modified starch
Alkali treated	–	Ingredient	Modified starch
Bleached	–	Ingredient	Modified starch
Oxidised starch	E1404	Additive	Modified starch
Monostarch phosphate	E1410	Additive	Modified starch
Distarch phosphate	E1412	Additive	Modified starch
Phosphated distarch phosphate	E1413	Additive	Modified starch
Acetylated distarch phosphate	E1414	Additive	Modified starch
Starch acetate	E1420	Additive	Modified starch
Acetylated distarch adipate	E1422	Additive	Modified starch
Hydroxypropyl starch	E1440	Additive	Modified starch
Hydroxypropyl distarch phosphate	E1442	Additive	Modified starch
Starch sodium octenyl succinate	E1450	Additive	Modified starch
Acetylated oxidised starch	E1451	Additive	Modified starch

Table 5.2 Summary of carrageenan properties

	Lambda	Iota	Kappa
Solubility			
Hot (80°C) water	Soluble	Soluble	Soluble
Cold (20°C) water	All water soluble	Na^+ salt soluble Ca^{++} salt gives thixotropic sols	Na^+ salt soluble Limited swelling of K^+, Ca^{++} salts
Hot (80°C) milk	Soluble	Soluble	Soluble
Cold (20°C) milk	Thickens	Insoluble	Insoluble
Cold milk (TSPP added)	Increased thickening or gelling	Thickens or gels	Thickens or gels
50% sugar solutions	Soluble	Insoluble	Soluble hot
10% salt solutions	Soluble hot	Soluble hot	Insoluble
Gelation			
Effect of cations	Non-gelling	Strongest gels with Ca^{++}	Strongest gels with K^+
Gel texture	–	Elastic	Brittle
Shear reversible gel	–	Yes	No
Syneresis	–	No	Yes
Hysteresis	–	5–10°C	10–20°C
Freeze-thaw stable	Yes	Yes	No
Synergy with locust bean gum	No	No	Yes
Synergy with konjac flour	No	No	Yes
Synergy with starch	No	Yes	No
Salt tolerance	Good	Good	Poor
Stability in acid	Hydrolysis	Hydrolysis of solution, accelerated by heat Gels are stable	
Protein reactivity	Strong interaction increasing at acid pH		Specific reaction with kappa-casein

Table 5.4 Typical applications for carrageenan in dairy products

Use	Function	Carrageenan type	Use level (%)
Milk gels			
Cooked flans	Gelation, mouthfeel	kappa, kappa + iota	0.2–0.3
Cold-prepared custards	Thickening, gelation	kappa, iota, lambda	0.2–0.3
Pudding and pie fillings	Reduced starch, lower burn-on	kappa	0.1–0.2
Ready-to-eat desserts	Syneresis control, mouthfeel	iota	0.1–0.2
Whipped products			
Whipped cream	Stabilise overrun	lambda	0.05–0.15
Aerosol cream	Stabilise overrun, emulsion stabilisation	kappa	0.02–0.05
Cold-prepared milks			
Shakes	Suspension, mouthfeel, stabilise overrun	lambda	0.1–0.2
Frozen desserts			
Ice cream, ice milk	Whey prevention, control meltdown	kappa	0.01–0.02
Pasteurised milks			
Chocolate milks	Suspension and mouthfeel	kappa	0.015–0.03
	Suspension and mouthfeel	kappa + lambda	0.03–0.10
Soy milks	Suspension and mouthfeel	kappa + iota	0.02–0.04
Sterilised milks			
Chocolate milks	Suspension and mouthfeel	kappa, lambda	0.01–0.03
Evaporated milks	Emulsion stabilisation	kappa	0.005–0.015
Processed cheese			
Cheese slices and blocks	Improve slicing and grating Control melting	kappa	0.5–3.0
Cream cheese and spreads	Gelation, moisture binding	kappa + locust bean gum	0.3–0.6

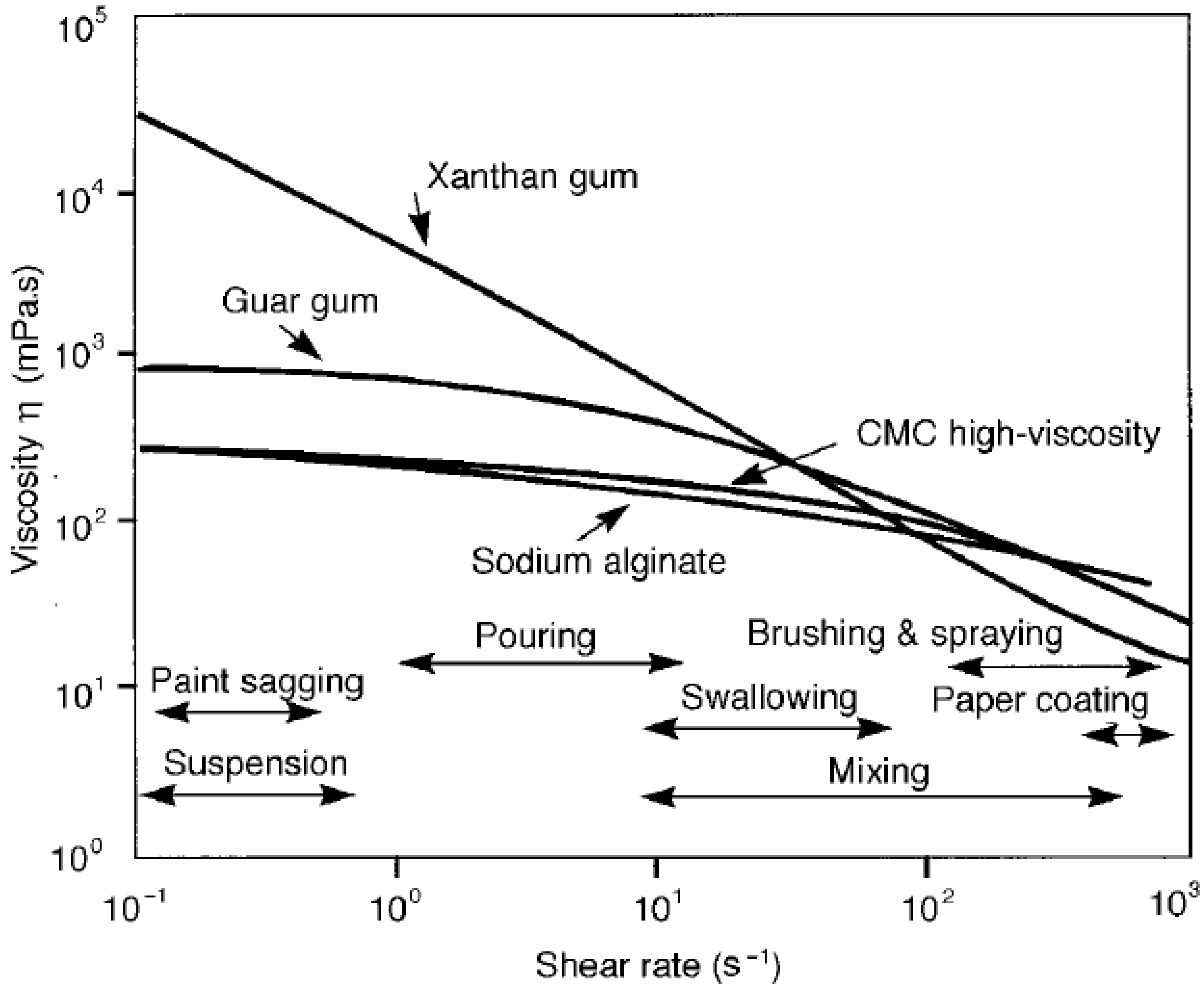

Fig. 6.6 Comparison of the flow behaviour of xanthan gum to other hydrocolloid solutions (0.5% concentration).

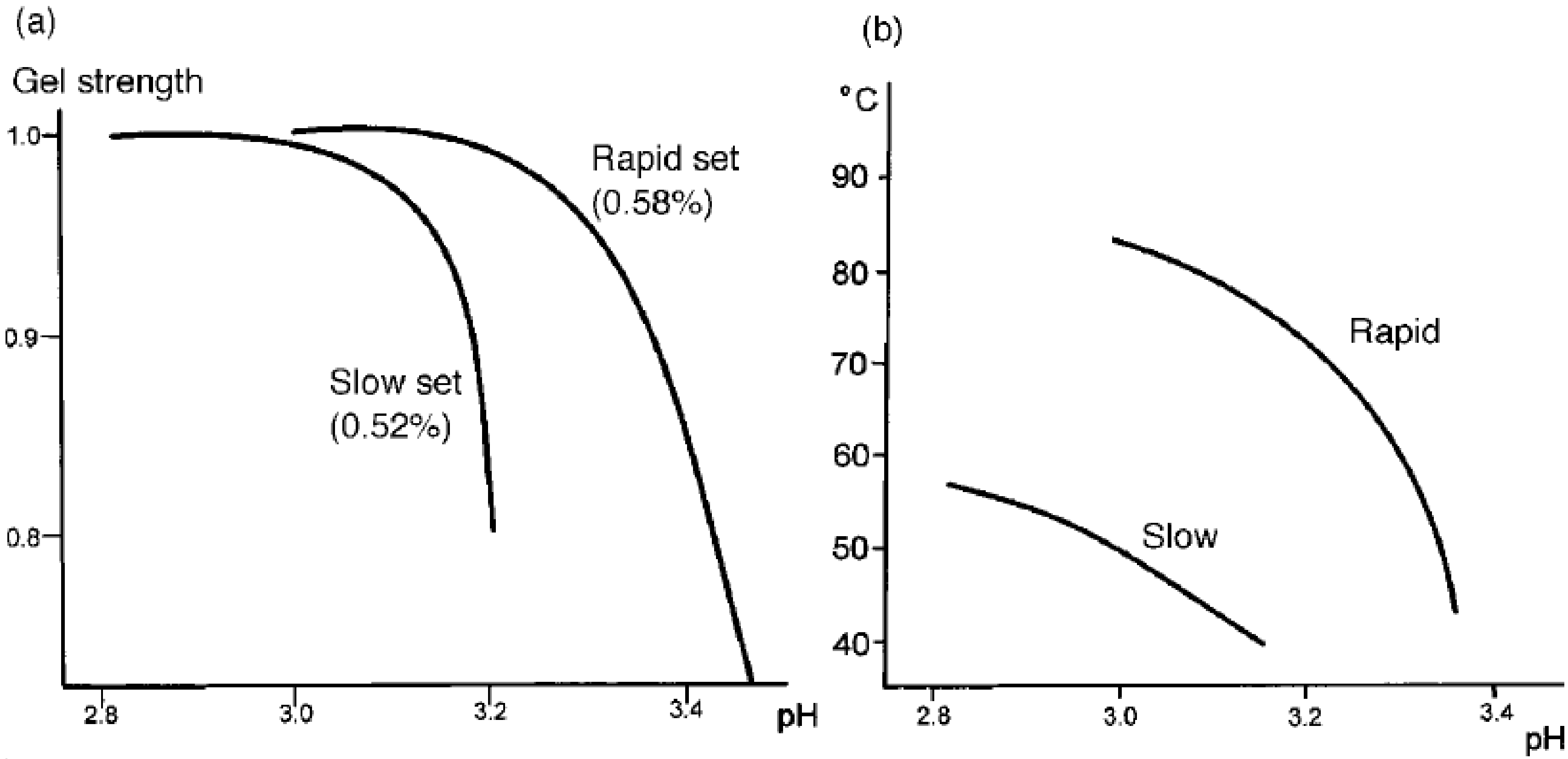

Fig. 10.3 (a) Variation of gel strength of high methoxyl pectins with pH in a 65% sucrose gel (relative values) (b) Variation of gel setting temperature in the same system.

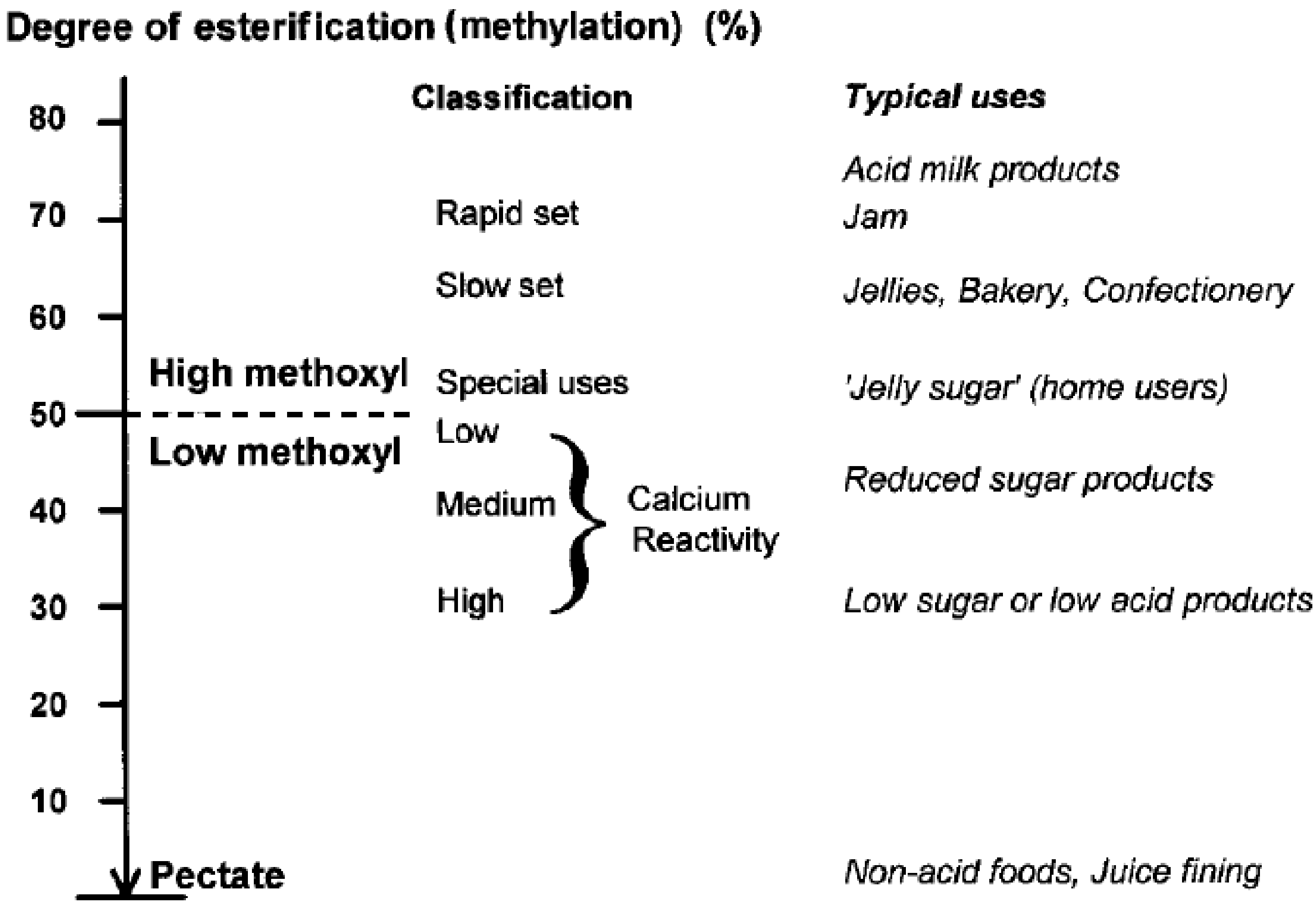

Fig. 10.5 The range of commercial non-amidated pectins with some typical applications.

Table 10.1 Typical pectin requirement for traditional jam at 65% soluble solids

	Fruit content %		
Fruit type	35	45	60
'Low pectin'			
e.g. strawberry, peach, raspberry, pineapple	0.30–0.39%	0.22–0.28%	0.11–0.16%
'Medium pectin'			
e.g. apricot, blackberry, marmalade	0.23–0.29%	0.15–0.22%	0.07–0.11%
'High pectin'			
e.g. apple, damson, gooseberry, plum, quince, redcurrant	0.14–0.21%	0.08–0.14%	0.0–0.07%

Formulation 10.2 Soft set orange marmalade

Ingredients		Weight (g)
A	Rapid set pectin	1.0
	Low methoxyl pectin	0.5
	Sucrose	10
B	Water	100
C	Orange pulp and peel	200
	Sucrose	640
	Water	150
D	Citric acid monohydrate (50% weight/vol.)	1.5 ml
Final batch weight		1 kg
pH (50% solution at 20°C)		3.0–3.2
Soluble solids (approximately)		67%

Preparation

1. Dry mix ingredients A and dissolve in water B, using a suitable high shear/speed mixer.
2. Heat ingredients C to the boil while stirring.
3. Add the pectin solution and boil down to 1015g.
4. While stirring add ingredients D, cool to 85°C and deposit into jars.

Formulation 10.3 Reduced sugar strawberry jam

Ingredients		Weight (g)
A	Amidated pectin, medium set	6
	Sucrose	30
B	Water	250
C	Strawberries	550
	Sucrose	325
D	Citric acid monohydrate (50% w/v)	4 ml
E	Potassium sorbate (20% w/v)	5 ml
Final batch weight		1 kg
pH (as is at 20°C)		3.2–3.4
Soluble solids (approximately)		43%

Preparation

1. Dry mix ingredients A and dissolve in water B using a suitable high shear/speed mixer.
2. Gently heat ingredients C to the boil. Add the pectin solution and boil down to 1020g.
3. With stirring add the citric acid D, followed by the potassium sorbate E.
4. Cool to 85°C and deposit.

Formulation 10.9 Milk/fruit juice drink

Ingredients		Weight (g)
A	Pectin (dairy stabiliser grade)	4
	Sucrose	10
B	Water	152
C	Skim milk powder	25
	Sucrose	80
D	Water	615
E	Fruit Juice	100
	Sucrose	10
	Citric acid monohydrate (50% w/v)	4 ml
Final batch weight		1 kg
pH (as is at 20°C)		3.9–4.1
Soluble solids (approximately)		15%

Preparation

1. Dry mix ingredients A and dissolve in water B using a suitable high shear/speed mixer.
2. Dry mix ingredients C and dissolve in water D.
3. Mix the pectin solution into the milk solution for 2–3 minutes using a suitable high shear/speed mixer.
4. With continuous mixing add ingredients E, and continue mixing for a further minute. Homogenise as required.
5. Pasteurise as necessary.