

CHAPTER 3

RESULTS AND DISCUSSION

3.1 Amylose content

The amylose content of native mungbean starch (MB) was determined by a colorimetric method, as described by Juliano (1971) that involves the complexation of amylose and KI/I_2 (Figure 3.1). The iodine-amylose complex was insoluble in water. It was yellow-to-green colloid solution (Figure 3.2). The complex was detected by UV/VIS spectrophotometer (Shimadzu™ UV-2450, Japan) at 620 nm. The amylose content was made comparison with an amylose standard curve that related between amylose standard concentration ($\mu\text{g/ml}$) and absorbance (A) at 620 nm. (Figure 3.2). The standard curve was established based on 2.06-10.30 $\mu\text{g/ml}$ of standard amylose ($r^2=0.9976$) (Figure 3.3). The results showed native MB has $37.35\pm 0.43\%$ of amylose (Table 3.1). This was in the same range (32.0-45.0%) as found for amylose in previous reports (Hoover et.al., 1991; Jung et.al., 1991; Kabir et.al., 1998; Kasemsuwan et.al., 1999; Ohwada et.al., 2003).

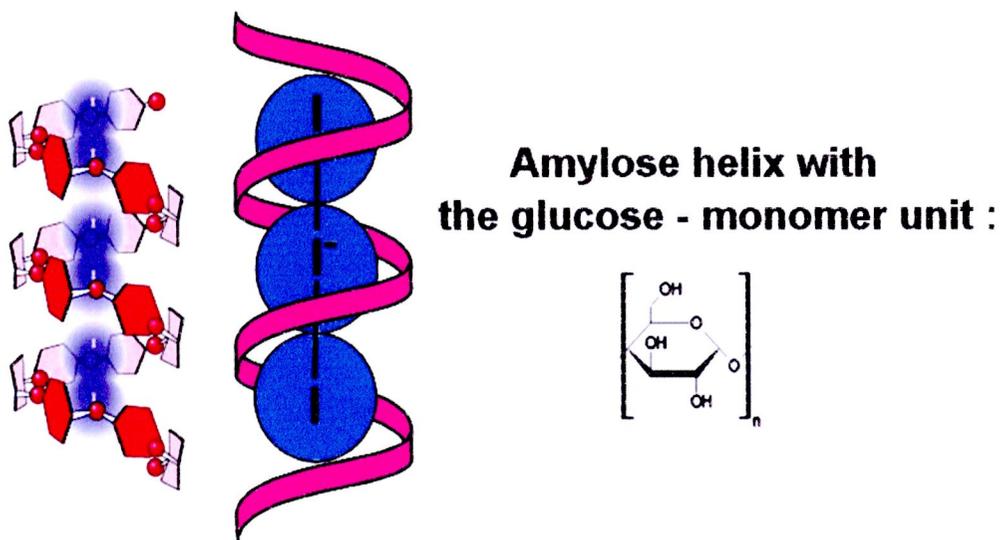


Figure 3.1 Iodine-amylose complex diagram

(Ref. : web.virginia.edu and www.whizurl.com)

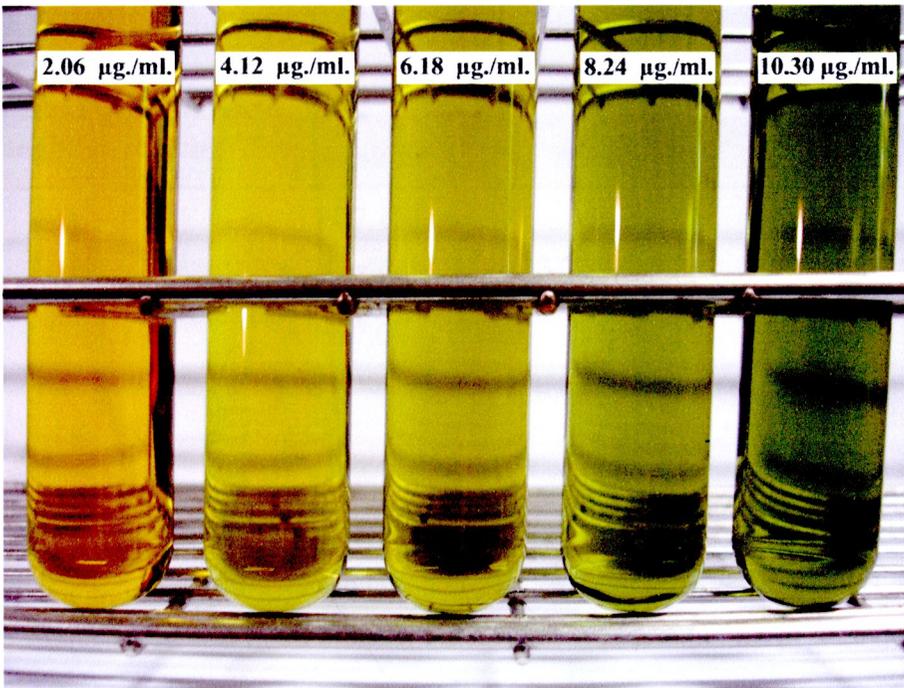
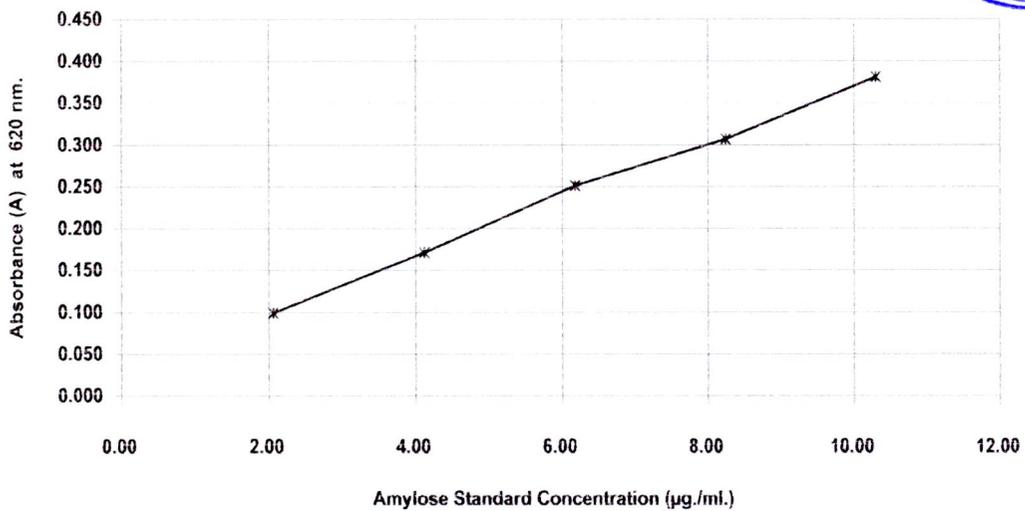


Figure 3.2 The complexation of amylose standard and KI/I_2



Amylose Standard Curve



$$y = 0.034x + 0.0318$$

$$\text{Correlation Coefficient ; } r^2 = 0.9976$$

Figure 3.3 Amylose standard curve at 620 nm.

Table 3.1 Amylose content of native mungbean starch

Native mungbean starch (Mungbean starch)	Results	Amylose content (%)	
		Average	Previous report**
MB - 1	37.15		
MB - 2	37.84	37.35±0.43	32.0-45.0
MB - 3	37.04		

** Hoover et.al., 1991; Jung et.al., 1991; Kabir et.al., 1998; Kasemsuwan et.al., 1999;

Ohwada et.al., 2003

3.2 Chemical starch modification

The reaction of carboxymethylation and/or cross-linking was modified in a three-necked, round-bottomed flask. The modification was conducted in a closed system with the starch modification apparatus (Figure 3.4). The apparatus was kept in 70°C with condenser to protect the evaporation of solvent and the temperature was controlled with thermometer.

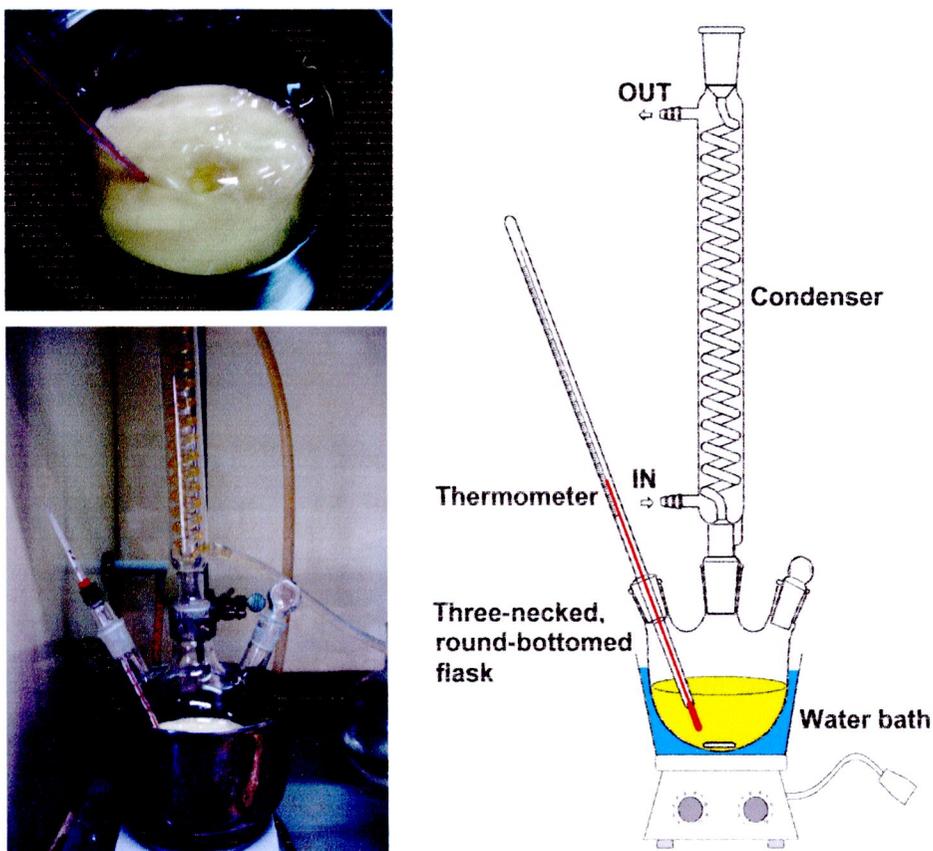


Figure 3.4 Starch modification apparatus

The modification of carboxymethyl modified mungbean starch (CMMS), Cross-linked modified mungbean starch (Cross-linked MB) and Cross-linked carboxymethyl modified mungbean starches (CL-MBs, 7 conditions) were carried out through the carboxymethylation and/or cross-linking between native MB, monochloroacetic acid (MCA) and/or dichloroacetic acid (DCA) with the single step reaction. The carboxymethylation and cross-linking was the etherification as a base-catalyzed substitution reaction, called *Williamson ether synthesis*. These is a nucleophilic displacement of alkyl halides by alkoxides (equation 1).



The conventional Williamson ether synthesis involves treatment of a parent alcohol with a strong base (liked sodium hydroxide, NaOH) to form the alkoxide, followed by addition of an appropriate aliphatic compound bearing a good leaving group ($\text{R}^1\text{-X}$), called an alkyl halide. The reaction uses an alkoxide ion to attack an alkyl halide, substituting the alkoxy ($-\text{O-R}$) group. The alkoxide ion is a powerful nucleophilic and reacts well with the good leaving groups (X^-), included iodide (I^-) bromide (Br^-), tosylate (*p*-toluenesulfonate, $\text{CH}_3\text{C}_6\text{H}_4\text{SO}_2\text{O}^-$), besylate (benzenesulfonate, $\text{C}_6\text{H}_5\text{SO}_2\text{O}^-$), mesylate (methanesulfonate, $\text{CH}_3\text{SO}_2\text{O}^-$), triflate (trifluoromethanesulfonate, $\text{CF}_3\text{SO}_2\text{O}^-$) or other sulfonates (RSO_2O^-). It only gives the best yields with primary alkyl halides so that the backside attack is not sterically hindered, or elimination will complete with the desired substitution. On the other hand, it usually does not work well for aryl halides. The mechanism will not work upon secondary or tertiary alkyl halides because of competition from the E_2 mechanism (E_2 elimination), which would form an alkene. The elimination products were depended on the alkoxide anion dued to steric hindrance from the large alkyl groups (Smith et.al., 1969; Vollhardt et.al., 2007).

CMMS, Cross-linked MB and 7 conditions CL-MBs were prepared by adding MCA and/or DCA to react with native mungbean starch via carboxymethylation reaction and/or cross-linking reaction, respectively. The temperature of mixture was increased and native MB mixture was changed to be yellowish mixture when

50%w/w NaOH solution was added on. The yellowish mixture was in a state of finishing step reaction. from adding NaOH. According to first step reaction, starch granule was slightly swelling owing to be catalyzed with NaOH. Carboxymethylation reaction and/or cross-linking reaction could be easily to react with these phenomenon. The native MB was reacted at $70\pm 2^{\circ}\text{C}$ for 60 min with reflux system to protect solvent evaporation and over burnt. At the end of reaction, glacial acetic acid was added into the mixture to stop the reaction by neutralization. With the neutralization, the starch granule was reverted to original condition as a slurry. The slurry was washed with several times 70-90% double distilled MeOH to remover by product (consisted of sodium chloride (NaCl), sodium acetate ($\text{CH}_3\text{COO}^- \text{Na}^+$) and disodium acetate ($\text{Na}^+ \text{CH}_2\text{COO}^- \text{Na}^+$). These salts caused an interruption of modified starches swelling as a result that they were tested by 1%w/w AgNO_3 solution with filtrant. The slurry was final washed with 100% MeOH when the filtrant was clear (without the white precipitate of silver chloride (AgCl), silver acetate ($\text{CH}_3\text{COO}^- \text{Ag}^+$) and disilver acetate ($\text{Ag}^+ \text{CH}_2\text{COO}^- \text{Ag}^+$)) after the test. The modified starch was dried in a hot air oven at 50°C for 24 hours and sieved with 80 mesh strainer. The finished powders of CMMS, cross-linked MB and CL-MBs were obtained as light yellowish, fine powders (Figure 3.5). The CL-MBs yield were between 95.67-97.75% (Table 3.2).

The appearance of native MB powder (Figure 3.5A) was as white, fine powder and coarse-grained. It was insoluble in cold water and when starch suspension was heated in water, it became paste. The paste of native MB was flexible, transparent, of high strength and homogeneous. These results were agreed with the amylose content experiment about 37.35%. Therefore, native MB contained high amylose starch.

On the other hand, the appearance of CMMS (Figure 3.5B) and 7 conditions of CL-MBs (Figure 3.5D-J) were opposite from the native MB. They were light yellowish, fine powder and fine-grained. They were soluble in cold water, forming gel. The gel was flexible, transparent, was of higher strength and more homogeneous than native MB paste at the same concentration.

Table 3.2 The appearances of CMMS, Cross-linked MB and CL-MBs vs MB

Types of starch	Appearances	Yield value (% yield)
Native mungbean starch (MB)	white, fine powder coarse-grained none gel formation	-
CMMS (C - MB - 100)	light yellowish white, fine powder fine-grained gel was formed	94.02
Cross-linked MB (L - MB - 100)	light yellowish white, fine powder fine-grained none gel formation	99.45
CL - MB - 1	} light yellowish white, fine powder fine-grained gel was formed	97.75
CL - MB - 4		97.40
CL - MB - 5		97.01
CL - MB - 7		95.67
CL - MB - 8		96.45
CL - MB - 9		96.85
CL - MB - 10		95.88

For cross-linked MB (Figure 3.5C), the appearance as light yellowish, fine powder and fine-grained was varied from the starting material, whereas it liked some other modified starch (CMMS and cross-linked MB). It's solubility was similar as the native MB. Cross-linked MB was difficult to disperse in the solvent, thus the precipitation was rapidly.

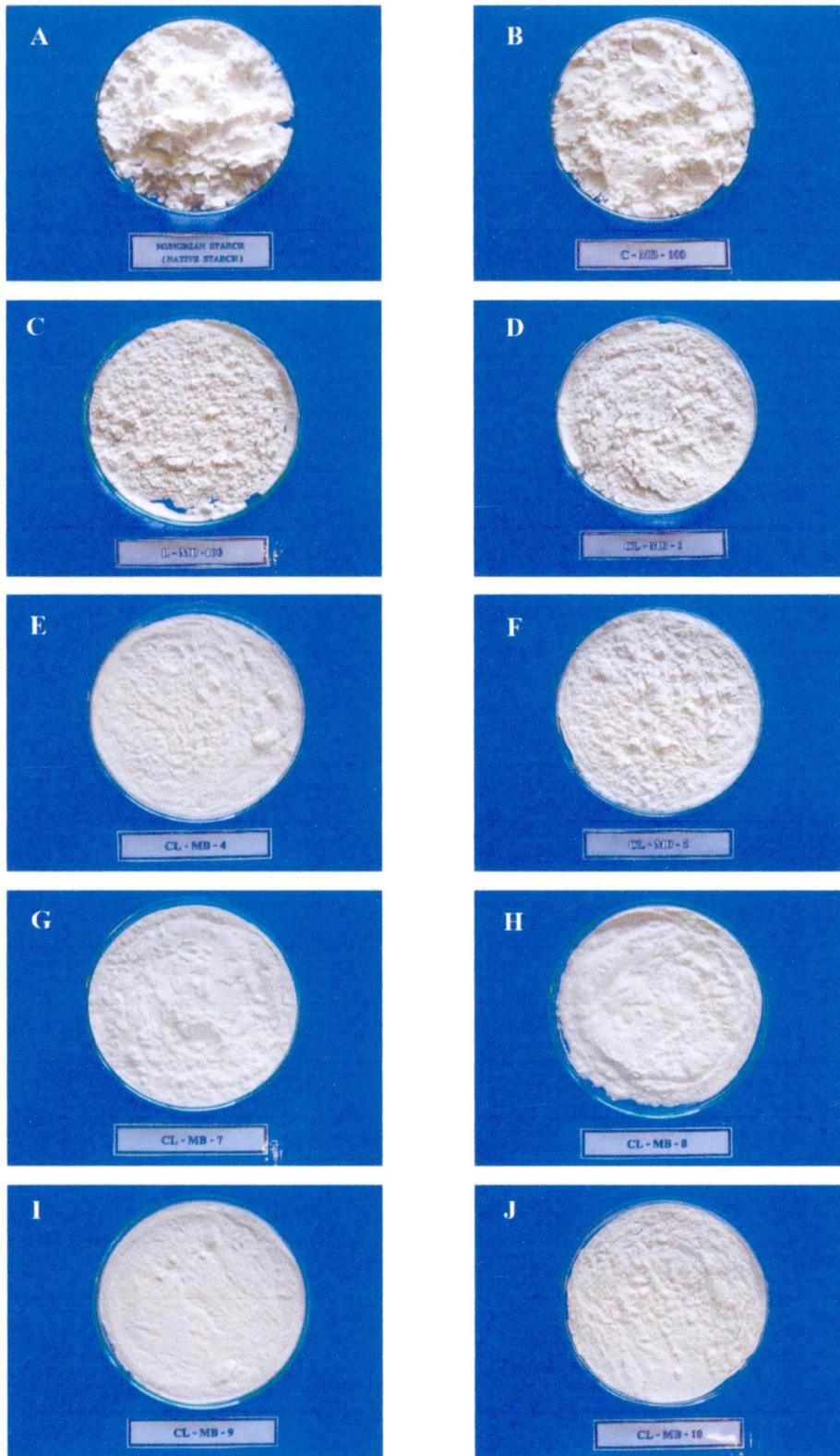


Figure 3.5 The comparison of cross-linked carboxymethyl modified mungbean starches (D-J) vs MB (A), CMMS (B) and cross-linked MB (C)

(D = CL-MB-1, E = CL-MB-4, F = CL-MB-5, G = CL-MB-7, H = CL-MB-8, I = CL-MB-9, J = CL-MB-10)

3.3 Modified starch identifications

3.3.1 Determination of degree of substitutions (DS)

The degree of substitution (DS) is the amount of carboxymethyl groups (-CO-CH₃) contained in the carboxymethyl starch network that substituted hydroxyl groups (-OH). The DS of modified starches were determined using a USP XXXII method, as described for sodium croscarmellose. The method consisted of titration step and a residue on ignition step. The DS value of CMMS was 0.3537, a result which agrees with a previous report (Kittipongpatana et.al., 2006). The DS value of CL-MBs ranged between 0.2121 and 0.2456. The DS value was linked with the intensity of the carbonyl group peak, determined by FT-IR analysis (Table 3.3).

Table 3.3 Degree of substitution (DS) of CMMS, cross-linked MB and CL-MBs with varied conditions

Types of modified starches	Degree of substitution (DS)
Carboxymethyl modified mungbean starch, CMMS (C - MB - 100)	0.3537
Cross-linked modified mungbean starch, Cross-linked MB (L - MB - 100)	0.0231
Cross-linked carboxymethyl modified mungbean starch, CL-MBs	
CL - MB - 1	0.2121
CL - MB - 4	0.2300
CL - MB - 5	0.2321
CL - MB - 7	0.2379
CL - MB - 8	0.2456
CL - MB - 9	0.2402
CL - MB - 10	0.2144

3.3.2 Scanning electron microscopy (SEM)

The morphology of the starch powder granules, and the surface and shape of the CL-MBs were analyzed using SEM. The appearance of starch granules after

modification was showed in Figure 3.6. The SEM image of native MB shows kidney-shaped image. The native MB was 4-16 μm width and 8-30 μm long (Figure 3.6A), agreed with the former times literatures (Kittipongpatana et.al., 2006 and Abdel-Rahman et.al., 2008). The CMMS (Figure 3.6B), cross-linked MB (Figure 3.6C) and 7-condition CL-MBs (Figure 3.6D-J) were showed an SEM image similar to native MB (Figure 3.6A). CMMS was soluble in cool water but cross-linked MB just dispersed.

In the case of CL-MBs, they were soluble in cool water and exhibited good swelling. These had similar properties as CMMS. The formation of a grooved surface can be observed on the starch granules with CL-MB-5 (3.6F), CL-MB-7 (3.6G), CL-MB-8 (3.6H), CL-MB-9 (3.6I) and CL-MB-10 (3.6J). The grooved surface was far below the surface, extending far downward when the concentration was increased.

3.3.3 Fourier transform infrared (FT-IR) spectroscopy

The FT-IR spectra, the substitution reaction of carbonyl group ($-\text{C}=\text{O}-$) was confirmed by a strong sharp peak at wave number 1600–1700 cm^{-1} . The FT-IR spectra of CMMS (Figure 3.7B) and CL-MBs (Figure 3.7D-J) show a strong absorption peck between wave number 1600 and 1650 cm^{-1} . This is a characteristic of the carbonyl group side-chain. The FT-IR spectra of modified starch (Figure 3.7B and 3.7D-J) are different from the native MB (Figure 3.7A), except cross-linked MB (Figure 3.7C). The hydroxyl group was substituted by a carbonyl group ($-\text{C}=\text{O}-$) or a carboxymethyl group ($-\text{CH}_2\text{COO}-$) from MCA. This strong peak was not show in native MB and cross-linked MB.

In the CMMS, a strong absorption peck of carbonyl group substitution and 7-condition CL-MBs were shown at wave number 1613.48 cm^{-1} (Figure 3.7B) and 1600–1650 cm^{-1} (Figure 3.7D-J), respectively. These was agreed with the former times literatures (Kittipongpatana et.al., 2006 and 2008). The strong peak of carbonyl group of cross-linked MB was disappeared at wave number 1600–1700 cm^{-1} (Figure 3.7C) that had similar as the FT-IR of native MB (Figure 3.7A). So, it was confirmed that DCA was not given the carbonyl group substitution to the side-chain of native MB.

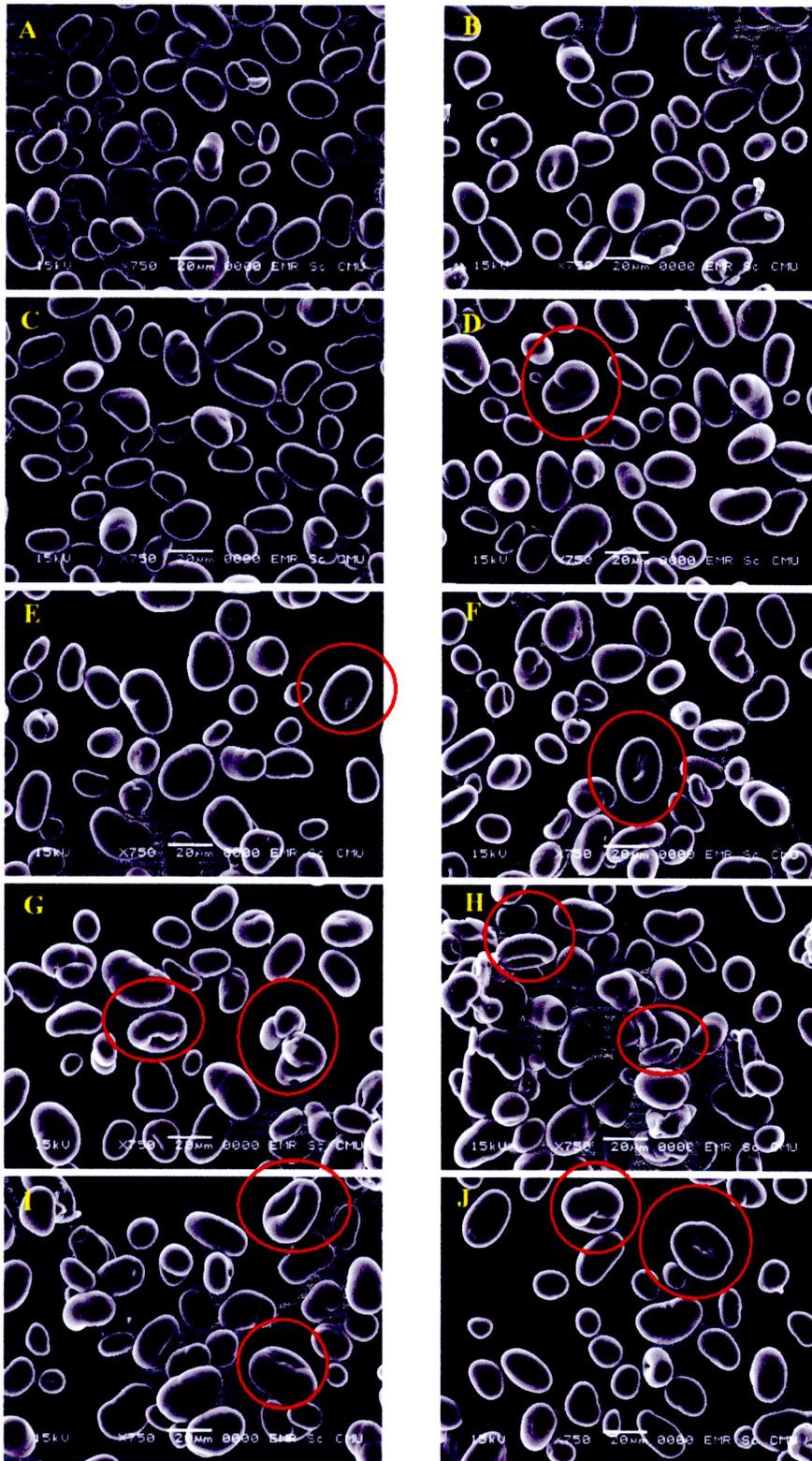


Figure 3.6 SEM of CL-MBs (D-J) compared with native mungbean starch (A),

CMMS (B) and cross-linked MB (C)

D = CL-MB-1, E = CL-MB-4, F = CL-MB-5, G = CL-MB-7, H = CL-MB-8, I = CL-MB-9, J = CL-MB-10

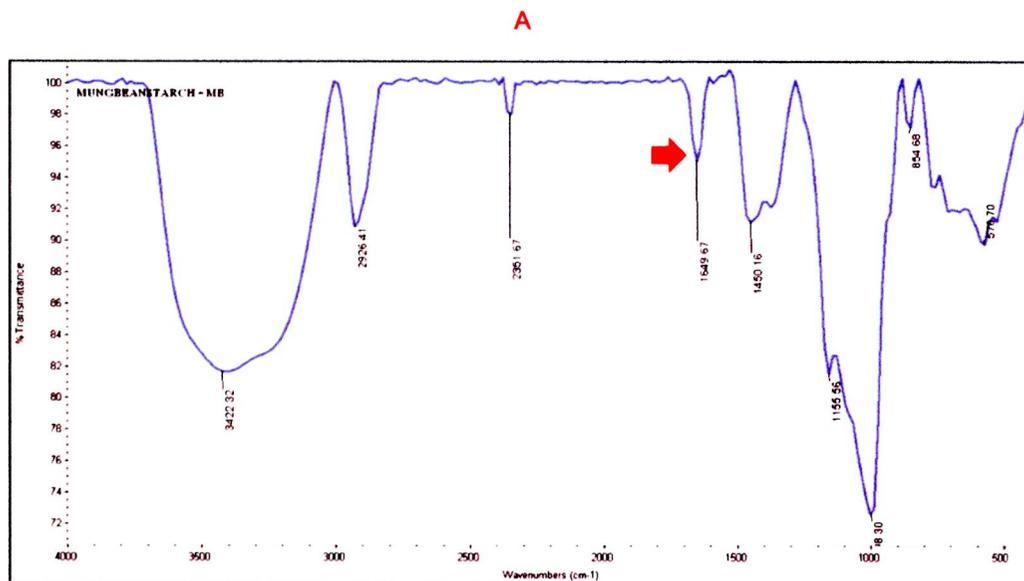


Figure 3.7A FT-IR spectrum of native mungbean starch which showed less intensity -COO⁻ peak at 1649.67 cm⁻¹

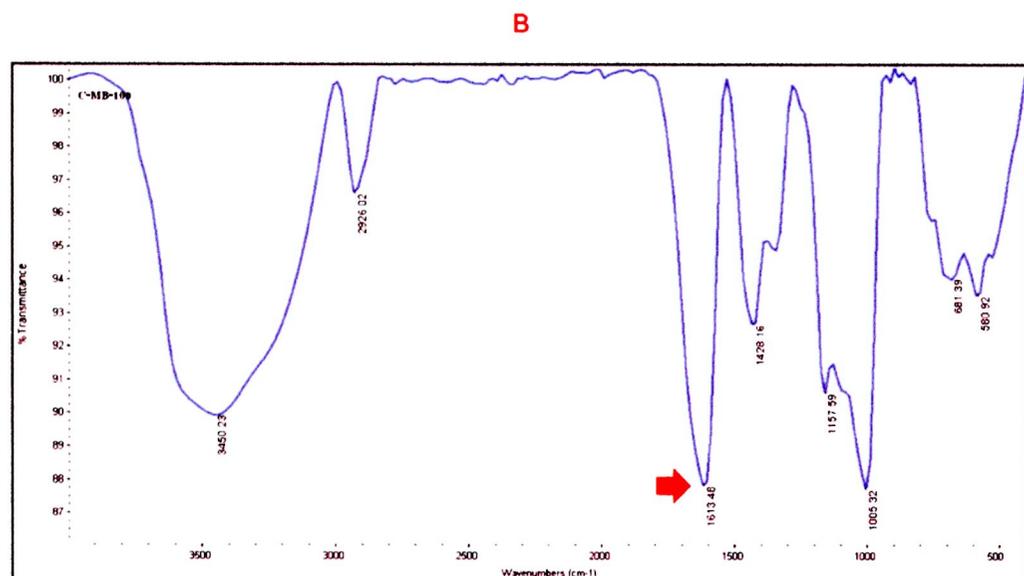


Figure 3.7B FT-IR spectrum of CMMS (C-MB-100) which showed strong intensity -COO⁻ peak at 1613.46 cm⁻¹

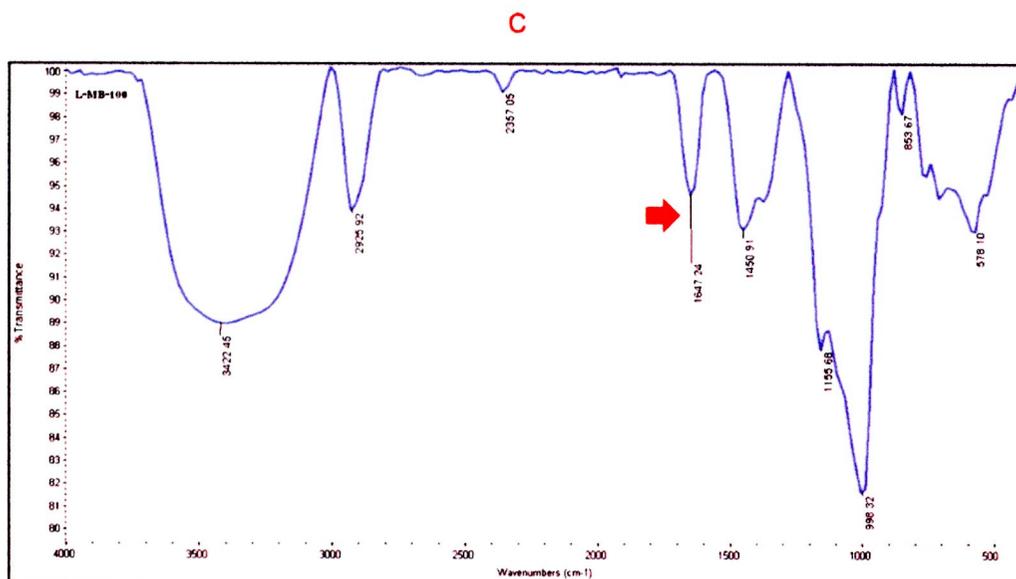


Figure 3.7C FT-IR spectrum of cross-linked MB (L-MB-100) which showed less intensity -COO⁻ peak at 1647.24 cm⁻¹

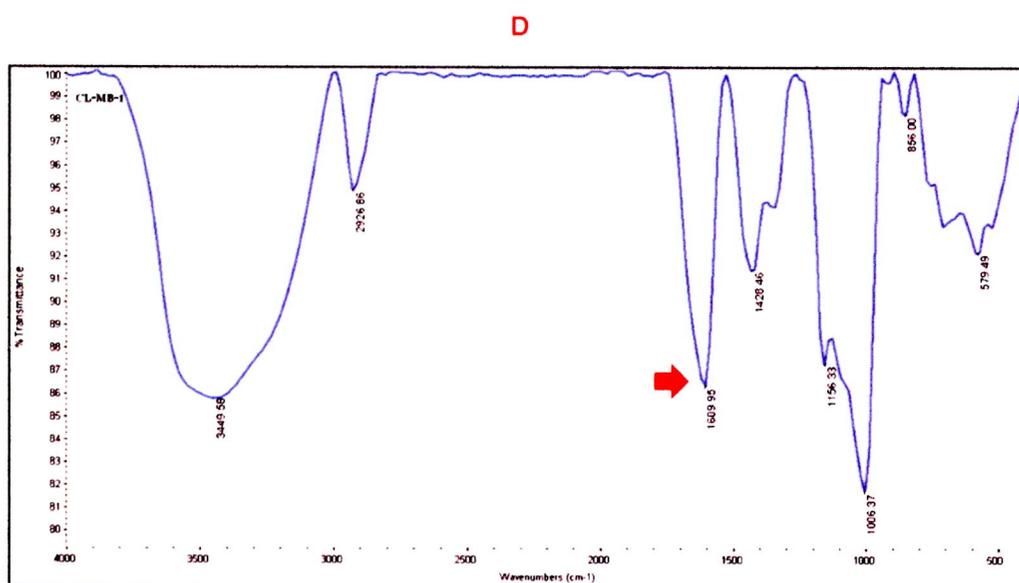


Figure 3.7D FT-IR spectrum of CL-MBs with DCA 1% which showed -COO⁻ peak at 1609.95 cm⁻¹

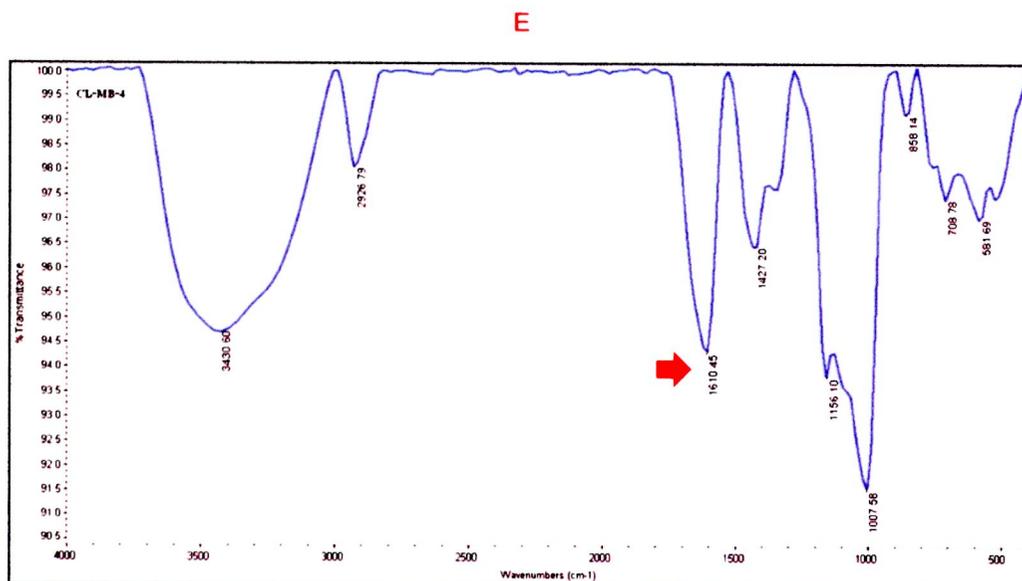


Figure 3.7E FT-IR spectrum of CL-MBs with DCA 4% which showed -COO^- peak at 1610.45 cm^{-1}

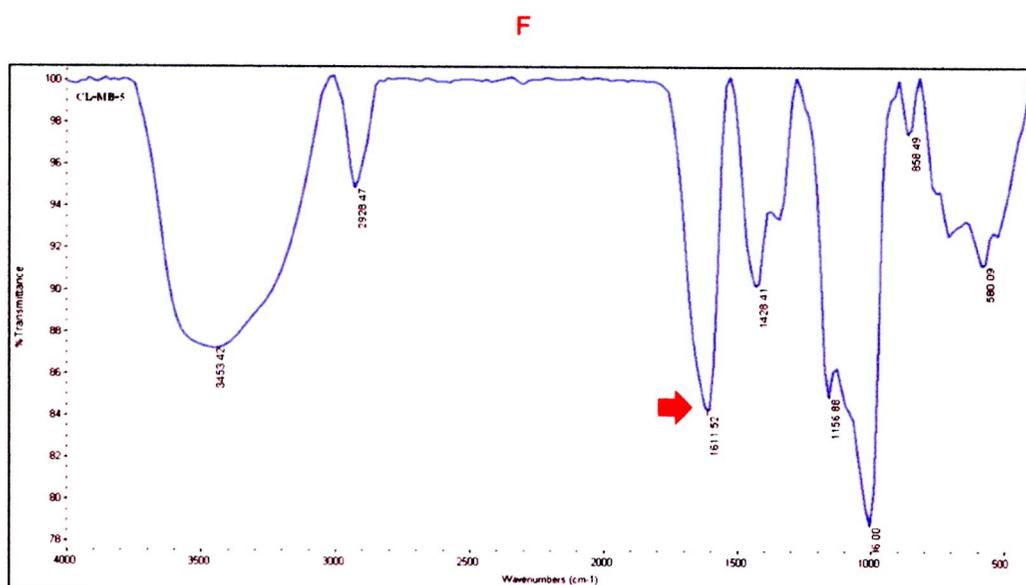


Figure 3.7F FT-IR spectrum of CL-MBs with DCA 5% which showed -COO^- peak at 1611.52 cm^{-1}

G

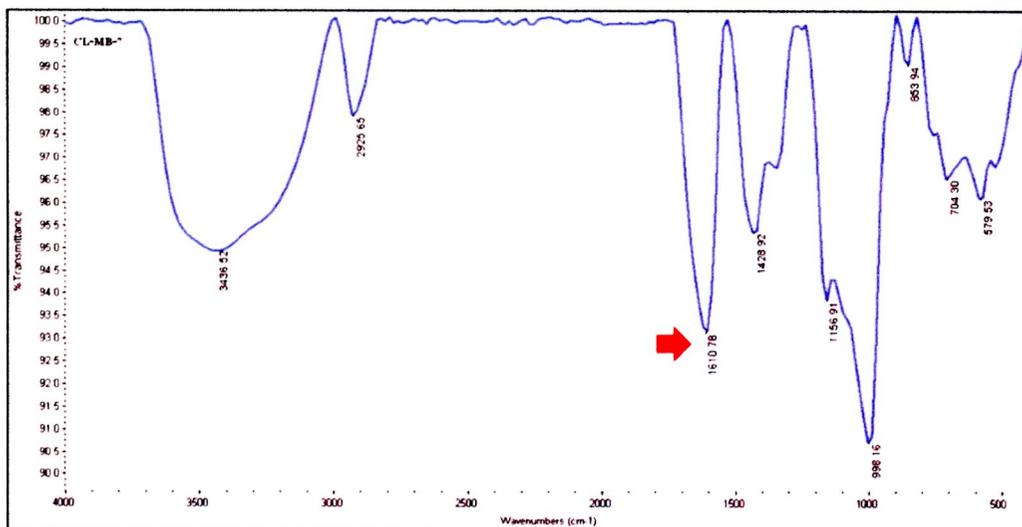


Figure 3.7G FT-IR spectrum of CL-MBs with DCA 7% which showed -COO^- peak at 1610.78 cm^{-1}

H

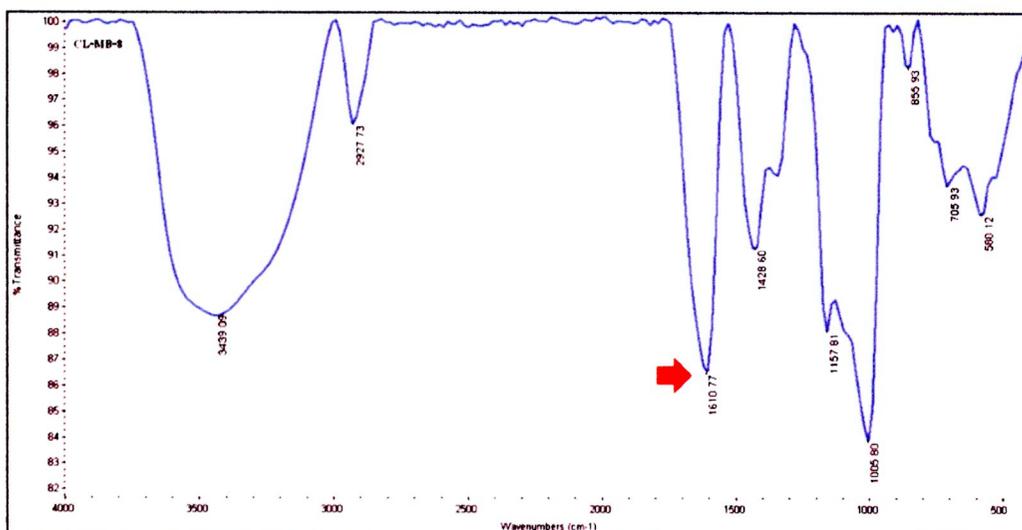


Figure 3.7H FT-IR spectrum of CL-MBs with DCA 8% which showed -COO^- peak at 1610.77 cm^{-1}

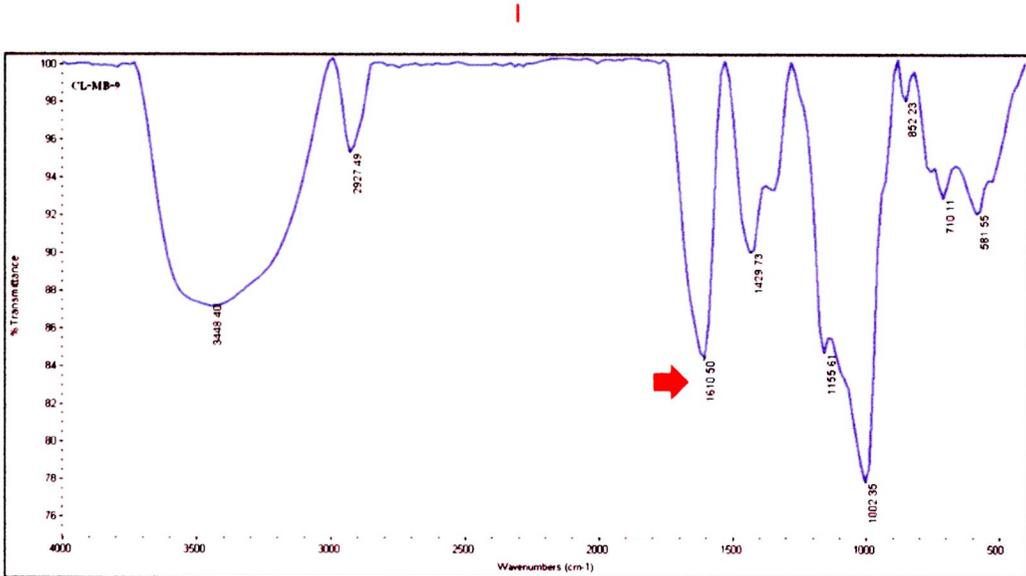


Figure 3.7I FT-IR spectrum of CL-MBs with DCA 9% which showed -COO^- peak at 1610.50 cm^{-1}

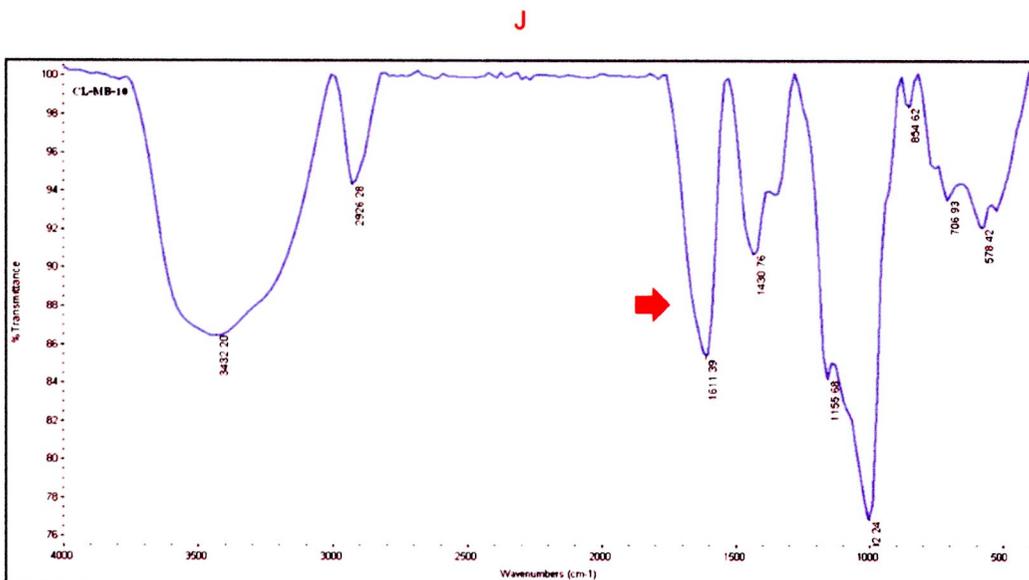


Figure 3.7J FT-IR spectrum of CL-MBs with DCA 10% which showed -COO^- peak at 1611.39 cm^{-1}

3.3.4 X-ray diffraction (XRD)

The X-ray diffractograms of native MB, CMMS, cross-linked MB and CL-MBs (Figure 3.8) exhibit strong diffraction peaks at 15.25, 17.43 and 23.05°2 θ . These values agree with the results found for C-type crystalline starches (at 5.6 and 17.9°2 θ , disappeared), showed the legume characteristic (Bogracheva et.al, 1998). The typical peak of the B-type crystalline starch is at 5.6°2 θ and the A-type crystalline starch is at 17.9°2 θ . (Gidley, 1987 and Cairns et.al., 1997).

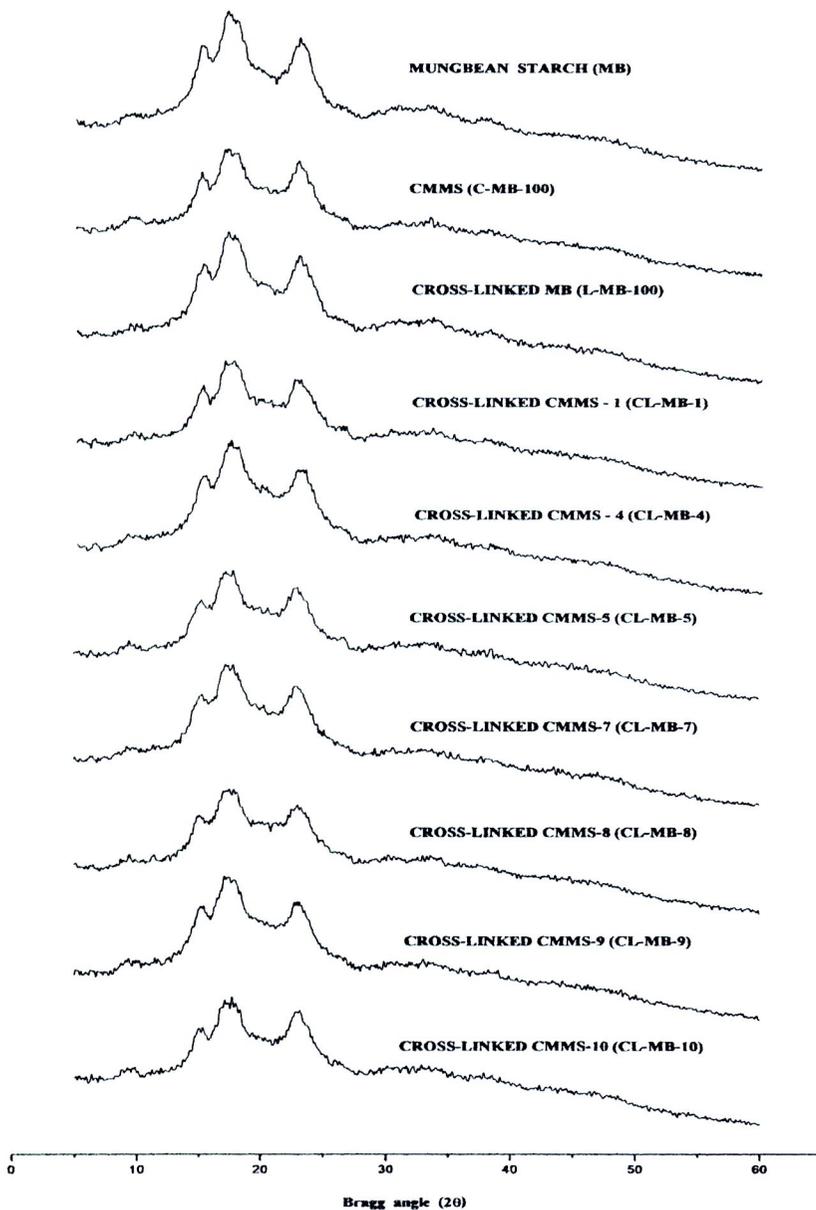


Figure 3.8 X-ray diffractograms of native mungbean starch, CMMS, cross-linked MB and CL-MBs

Figure 3.8, the spectra of CMMS and 7-condition CL-MBs showed a slightly decrease in the signal intensity, corresponding to a bit decrease in the crystalline polymorph of native MB (no significance). The signal intensity of cross-linked MB was not different from the native MB.

3.3.5 Cold-water solubility

CMMS and CL-MBs were soluble in cool water. The solutions of CMMS and CL-MBs were turbid when the concentrations of both CMMS and CL-MBs were increased. These results are supported by Kittipongpatana et.al. (2006). The cross-linked MB was insoluble in cool water.

Figure 3.9D-J, CL-MBs were rapid to swelling, corresponding with the free swelling capacity (FSC) value. The CL-MBs was swiftly swelling in cold-water and clear when these were compared with CMMS (Figure 3.9B).

For cross-linked MB, it was insoluble in water as same as native MB (Figure 3.9A), corresponding with the antecedent literatures. The solubility of modified starch was reduced with the high cross-linking (Kerr et.al., 1950 and Rutenberg et.al, 1984)

3.4 Physicochemical properties study

3.4.1 Moisture content

The specification of modified starch was referred to the monograph of croscamellose sodium and modified starch in USP XXXII. The moisture content was not more than 10% of its weight. In Table 3.4, the moisture content of modified starched became lower compared to that of the native starch. This pattern is related to the reaction between the hydroxyl groups (-OH) of glucose units of starch and the functional chemical reagent used in this chemical modification, decreasing the possibility of reaction between the hydroxyl groups of starch chains and the water molecules and consequently the join of water to this polymer. The CL-MB-7 was shown the least dampness and the extremely humidity was CL-MB-1. So, the sequential of moistness was CL-MB-7 < CL-MB-8 < CL-MB-9 < CL-MB-10 < CL-MB-5 < CL-MB-4 < CL-MB-1

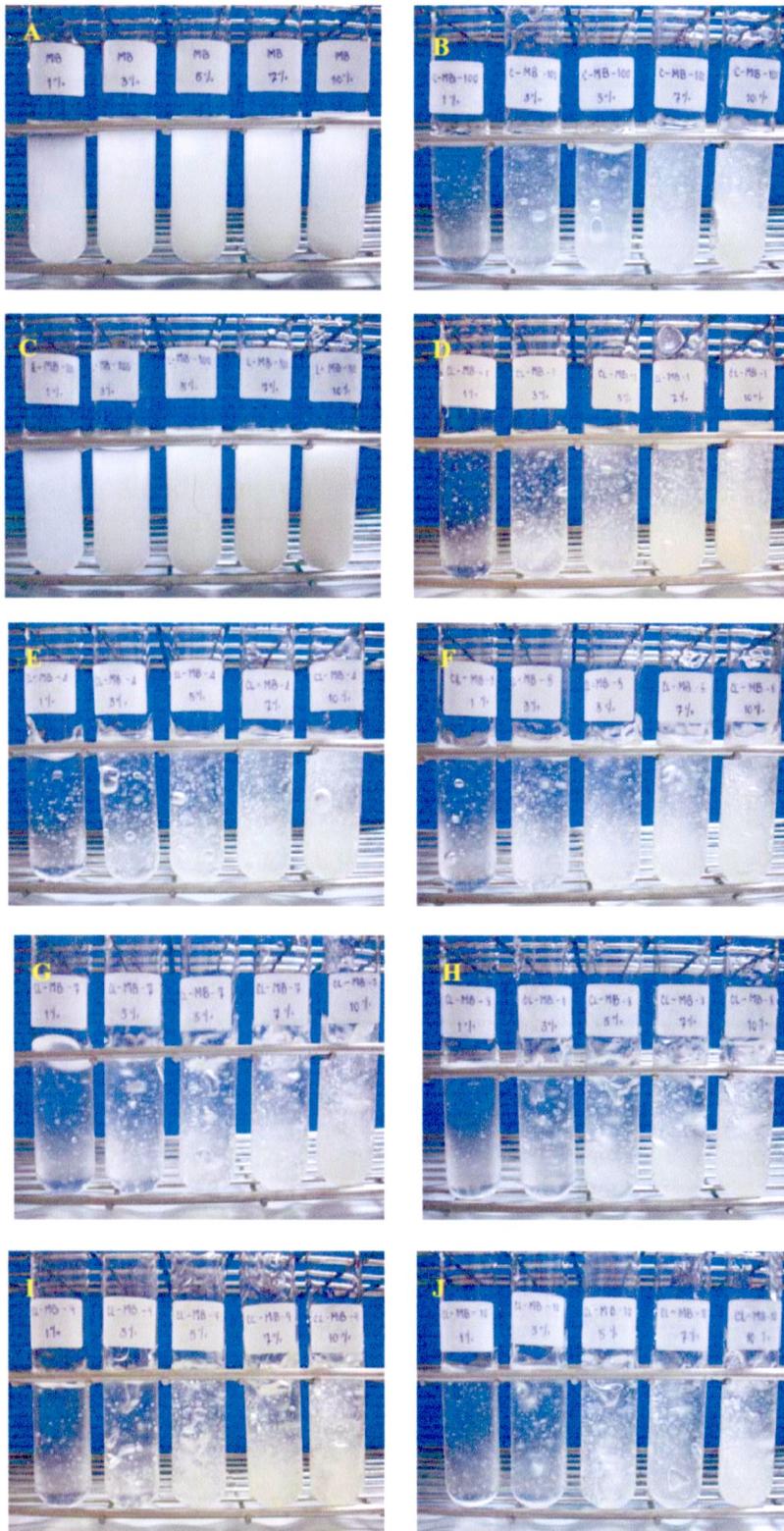


Figure 3.9 Cold-water solubility of CL-MBs compared with CMMS (B), cross-linked MB (C) and native mungbean starch (A)

(D = CL-MB-1, E = CL-MB-4, F = CL-MB-5, G = CL-MB-7, H = CL-MB-8, I = CL-MB-9, J = CL-MB-10)

Table 3.4 Moisture content of CMMS, cross-linked MB and CL-MBs with varied conditions

Types of modified starches	Moisture content (% of its weight)
Native mungbean starch (MB)	10.169±0.08
Carboxymethyl modified mungbean starch, CMMS (C - MB - 100)	9.832±0.03
Cross-linked modified mungbean starch, Cross-linked MB (L - MB - 100)	8.747±0.01
Cross-linked carboxymethyl modified mungbean starch, CL-MBs	
CL - MB - 1	9.246±0.04
CL - MB - 4	8.763±0.02
CL - MB - 5	8.664±0.03
CL - MB - 7	8.181±0.02
CL - MB - 8	8.259±0.02
CL - MB - 9	8.314±0.04
CL - MB - 10	8.491±0.05

3.4.2 Free swelling capacity (FSC)

The FSC of CL-MBs was determined by using the teabag method (Figure 3.10), as described by Christoph et.al. (2007). The FSC was compared with CMMS, cross-linked MB and four commercial polymers, including CP, MC, HPMC and SCMC, the results of which are shown in Table 3.5 and Figure 3.11.

CL-MB-7, CL-MB-8, CL-MB-9 and CL-MB-10 showed the higher FSC values than CMMS, cross-linked MB and the 4-commercial polymer. The CL-MB-7 had completely swelled after 180 minutes (100.0063 ± 0.01) and had swollen to 100 times its starting weight. It showed the highest FSC value (87.6421 ± 1.08) after 15 minute, though a higher FSC value was observed in CL-MB-7, CL-MB-8, CL-MB-9 and CL-MB-10, compared with the others.

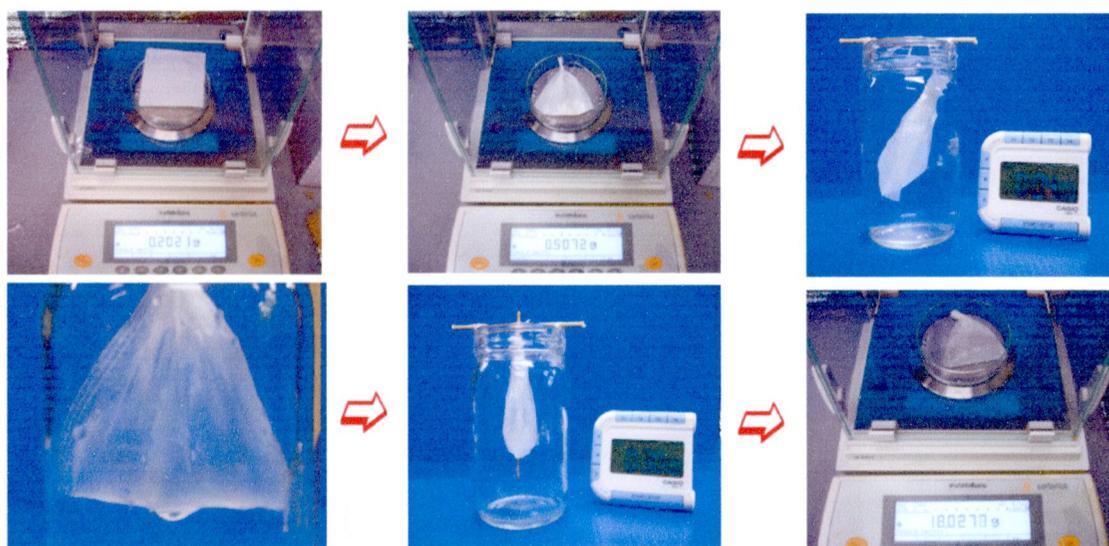


Figure 3.10 Free swelling capacity (FSC) protocol

3.4.3 The particularities of cross-linked carboxymethyl modified mungbean starch gels in distilled water

The modified starch powder was dissolved in ethanol (EtOH): water (H₂O) mix of ratio 0:100 at 1, 3 and 5%w/v concentration, compared with 4-commercial polymers : CP, MC, HPMC and SCMC. The gels were stored at 8°C and 45°C, and underwent a heating-cooling (HC) stability (8 cycles—each cycle consisted of 2 days at 8°C and another 2 days at 45°C), as shown in Figure 3.12A-3.12N.

CL-MBs and CMMS were soluble in cool water. The polymer gel in distilled water was flexible, transparent, was of high strength and homogeneous as similar to three commercial polymers - MC, HPMC and SCMC, but they were different from that of CP. With the observation, the viscosity of polymer gel that made of CL-MBs and CMMS were increased at the high concentration; though the gel is turbid at high concentrations. CL-MB-7, CL-MB-8, CL-MB-9, and CL-MB-10 have had the highest viscosity at the same concentration. Their viscosity were less than four commercial polymers - CP, MC, HPMC and SCMC. However, the CL-MBs formed gel when dissolved in water.

The bacterial growth could not be solved with the carboxymethylation and cross-linking. So, the preservative such as paraben conc. was added into the gelling agent in the pharmaceutical applications.

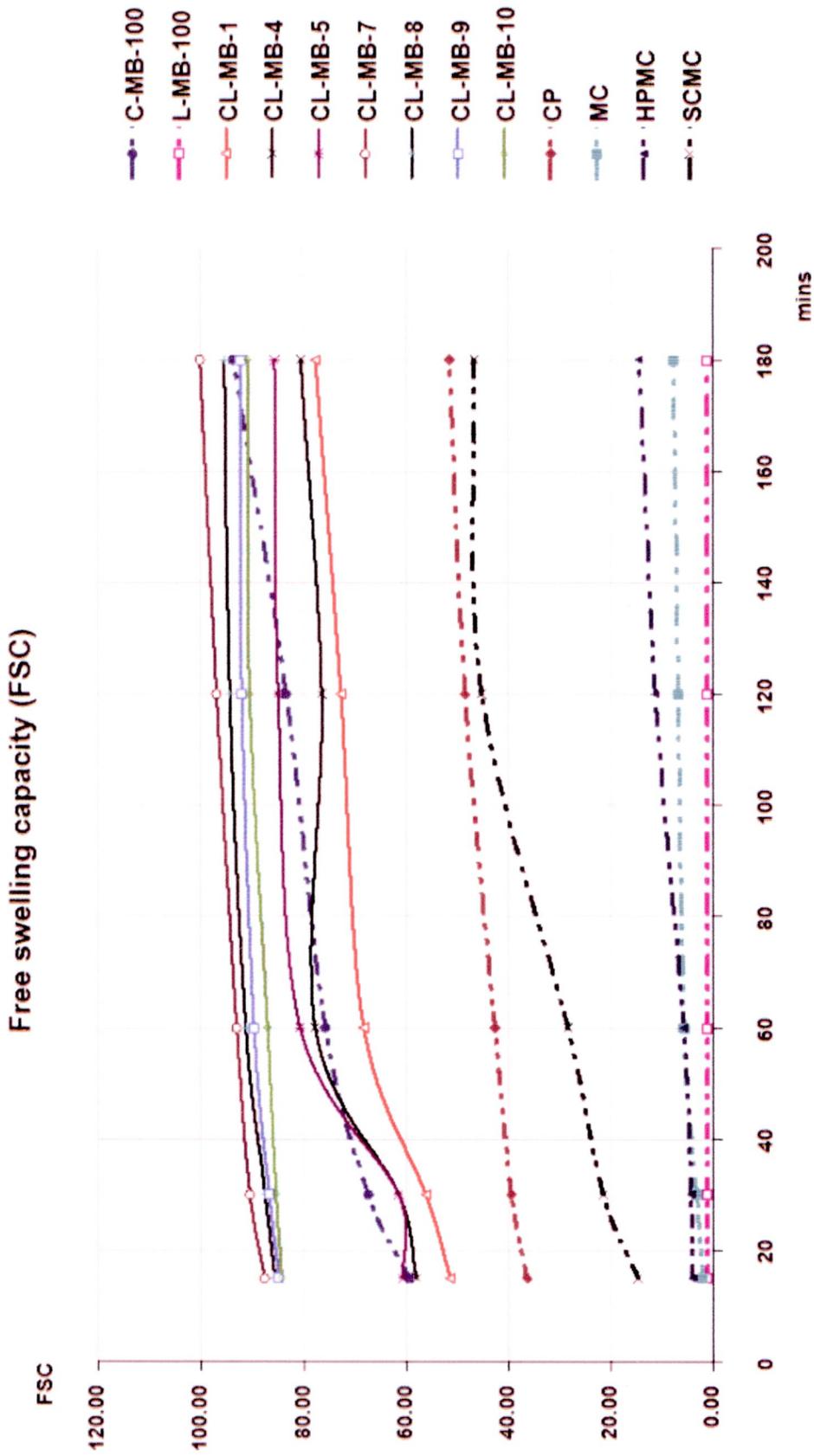


Figure 3.11 FSC of CL-MBs with varied conditions compared with CMMS, cross-linked MB and commercial polymers

Table 3.5 FSC of CL-MBs with varied conditions compared with CMMS, cross-linked MB and commercial polymers

Polymers	Free Swelling Capacity (FSC)				
	15 min	30 min	60 min	120 min	180 min
C-MB-100	59.4306±1.14	67.4111±1.20	75.7603±0.42	83.2727±1.46	93.5742±0.62
L-MB-100	1.0007±0.01	1.0015±0.04	1.0007±0.01	1.0010±0.02	1.0000±0.01
CL-MB-1	51.4098±0.84	56.1360±0.53	68.2388±1.03	72.6696±1.26	77.5961±0.60
CL-MB-4	57.9992±0.87	61.4413±0.84	77.6983±0.64	76.4320±0.38	80.4761±0.25
CL-MB-5	60.7189±1.27	61.5412±0.81	80.6847±0.35	84.9245±0.60	85.5924±0.42
CL-MB-7	87.6421±1.08	90.4324±0.26	93.0266±0.54	96.8929±0.72	100.0063±0.01
CL-MB-8	85.6195±0.86	87.5080±0.54	91.2368±0.98	94.3468±1.52	95.3601±0.35
CL-MB-9	84.8520±0.97	86.6514±0.86	89.6500±0.41	91.9493±1.33	92.0758±0.81
CL-MB-10	84.2336±0.99	85.3768±0.98	86.9821±1.08	90.3913±1.38	90.7533±1.64
CP	36.4248±0.52	39.5041±0.40	42.6423±0.72	48.4365±0.90	51.4846±0.72
MC	1.8871±0.03	3.2310±0.05	5.6714±0.06	6.7598±0.11	7.6343±0.14
HPMC	4.0688±0.06	4.3250±0.07	5.7092±0.10	11.2387±0.13	14.4205±0.23
SCMC	14.6456±0.25	21.4824±0.39	28.4033±0.36	45.1829±0.35	46.6953±0.47

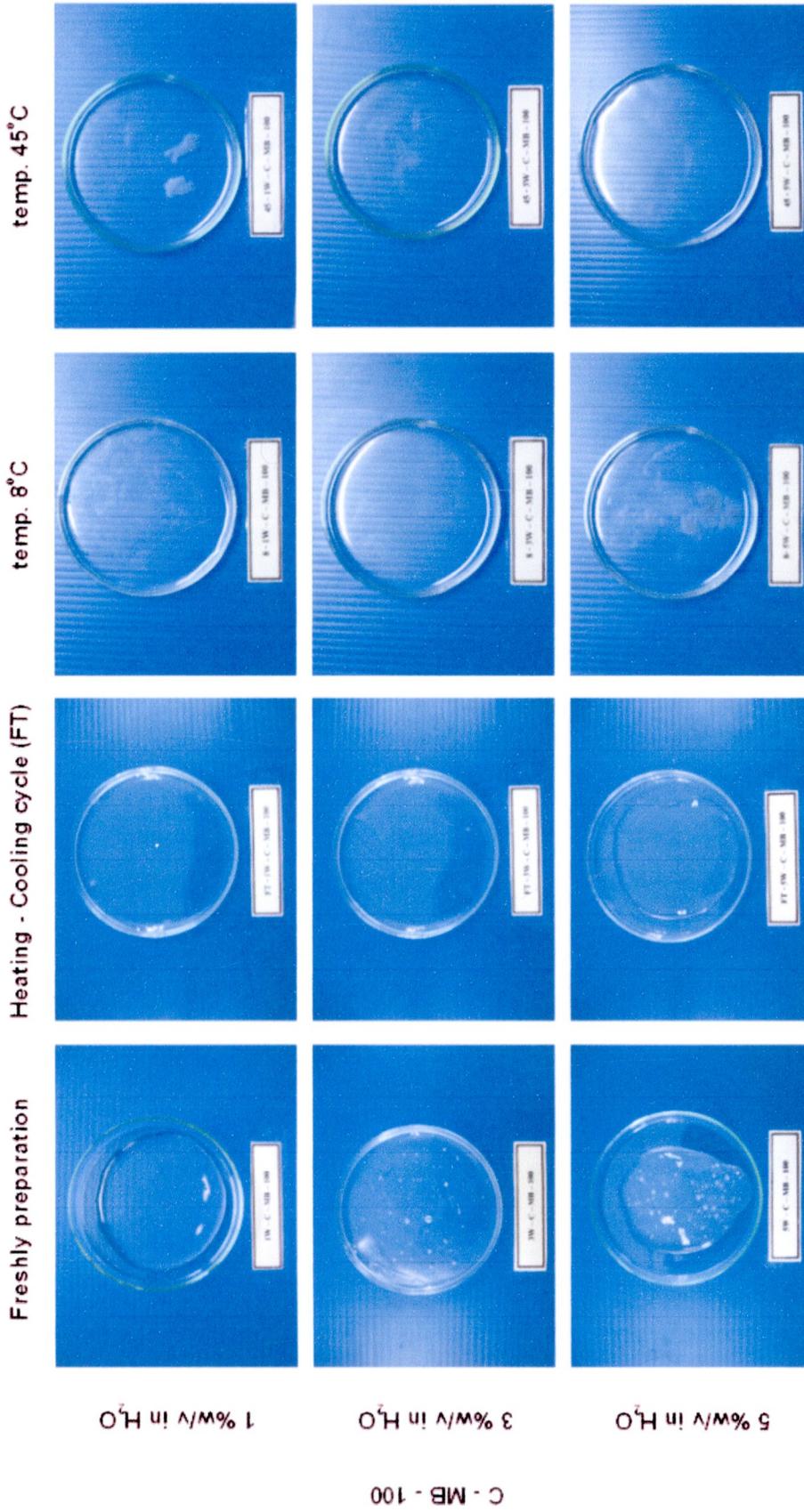


Figure 3.12A Stability of carboxymethyl modified mungbean starch (C-MB-100) gel in H₂O

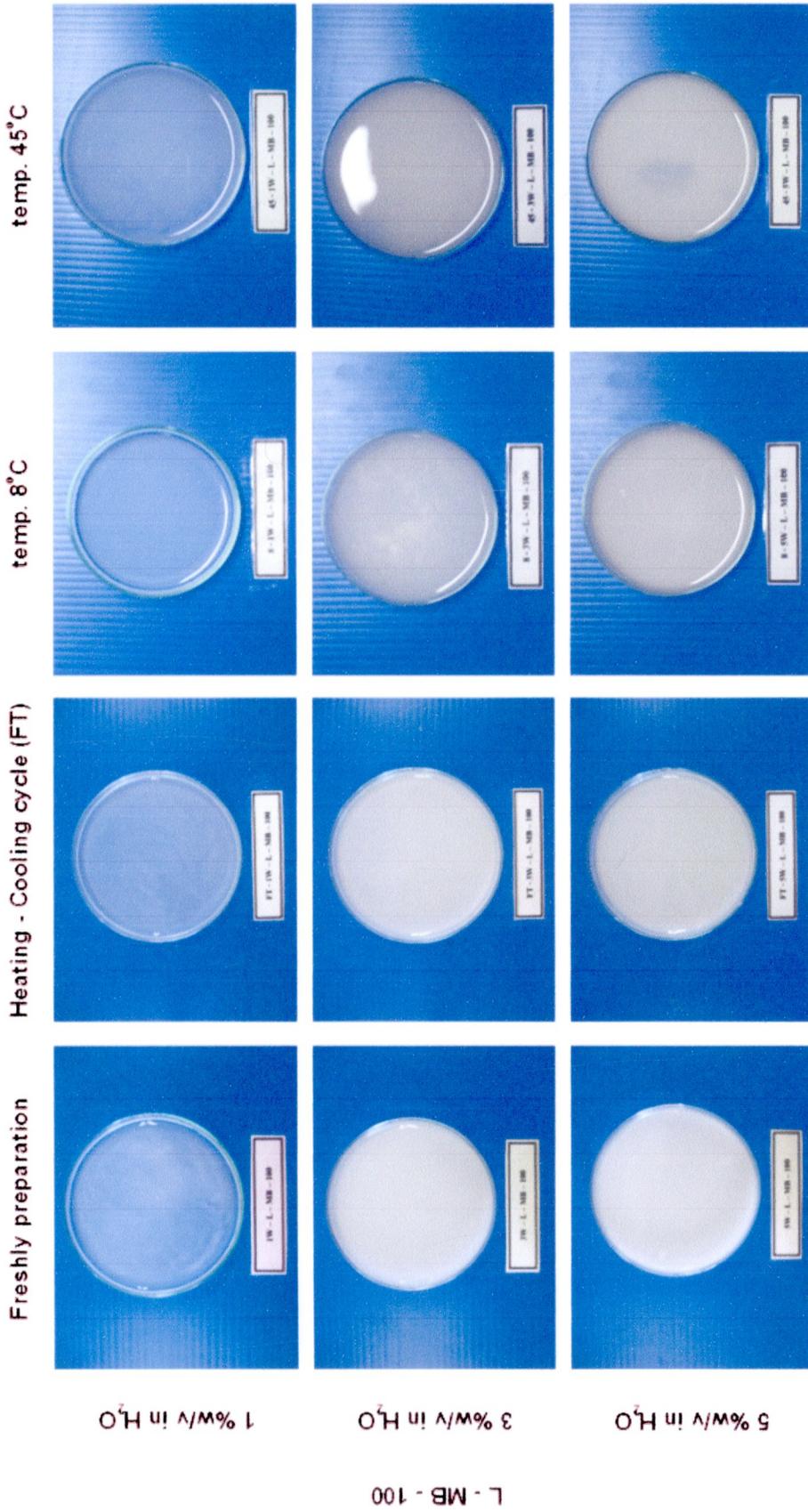


Figure 3.12B Stability of cross-linked modified mungbean starch (L-MB-100) suspension in H₂O

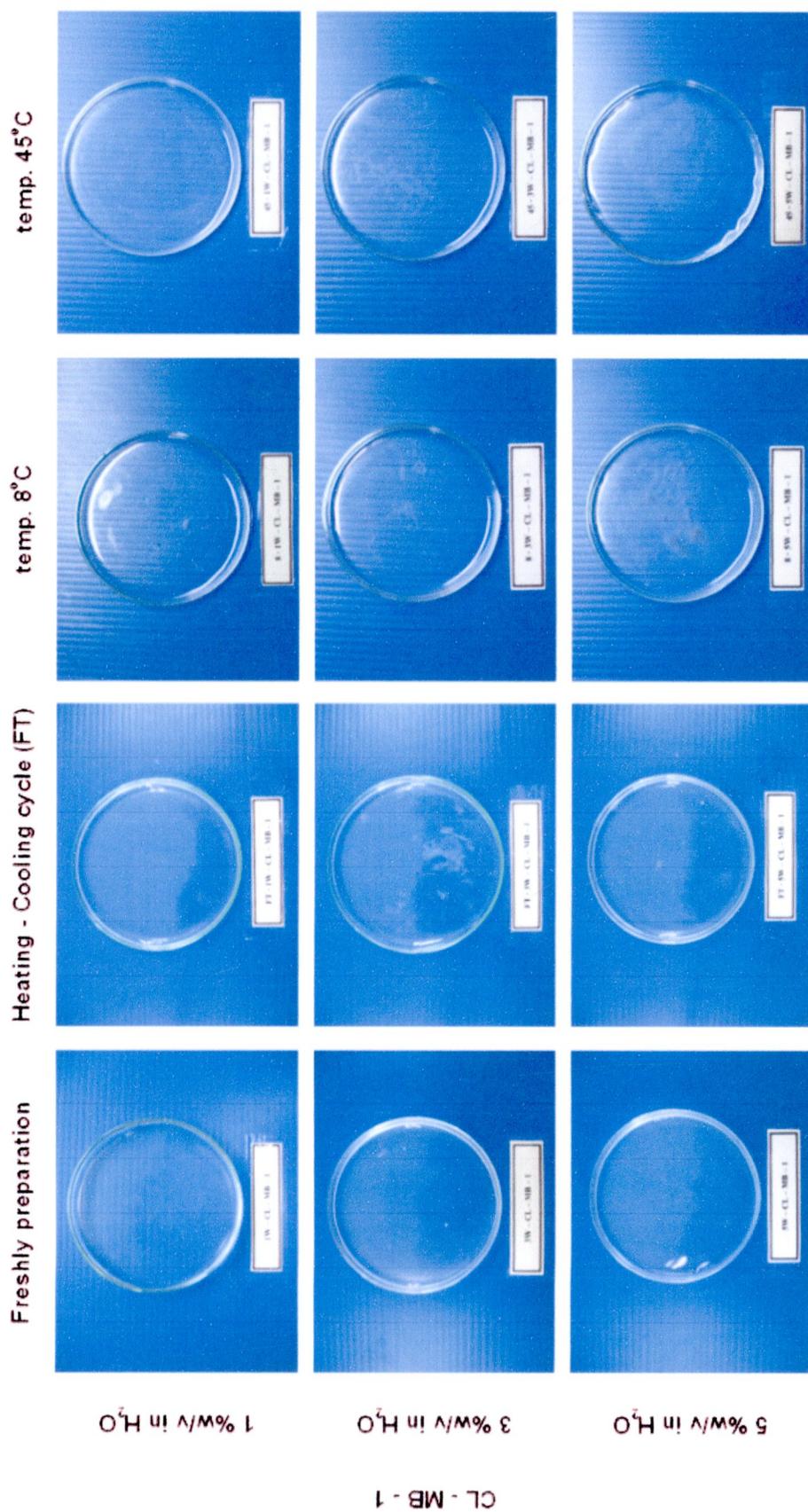


Figure 3.12C Stability of cross-linked carboxymethyl modified mungbean starch with DCA 1% (CL-MB-1) gel in H₂O

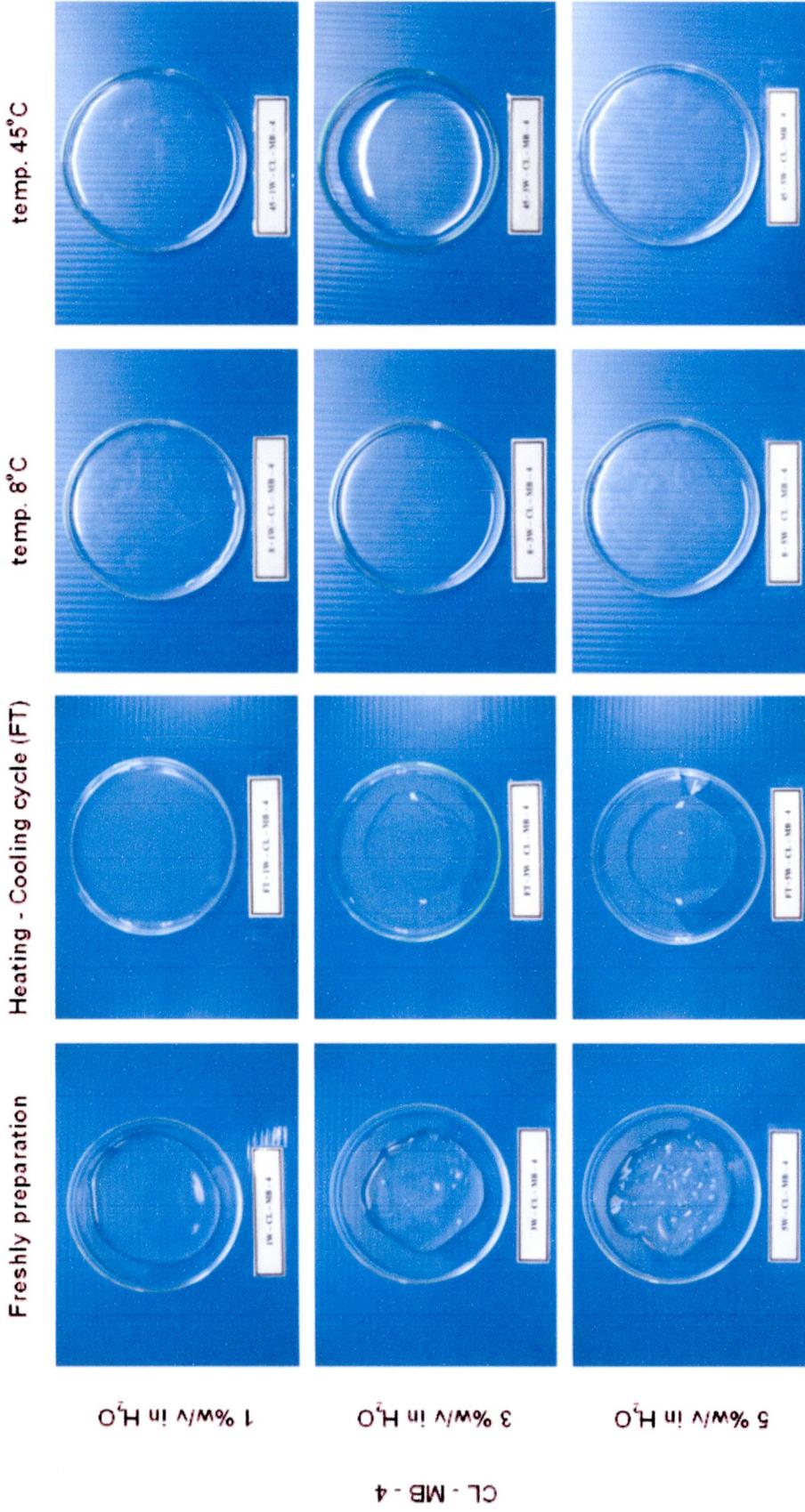


Figure 3.12D Stability of cross-linked carboxymethyl modified mungbean starch with DCA 4% (CL-MB-4) gel in H₂O

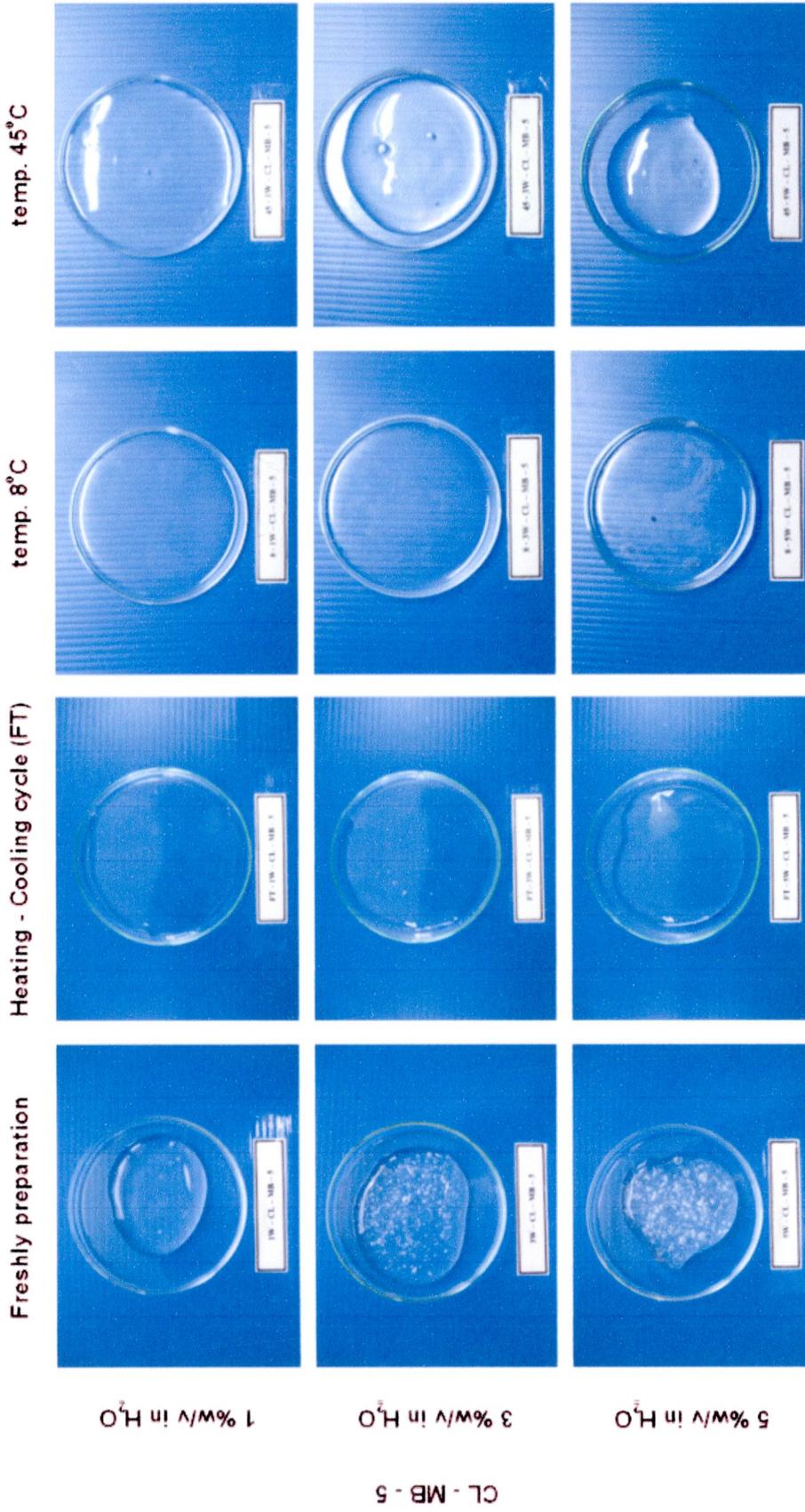


Figure 3.12E Stability of cross-linked carboxymethyl modified mungbean starch with DCA 5% (CL-MB-5) gel in H₂O

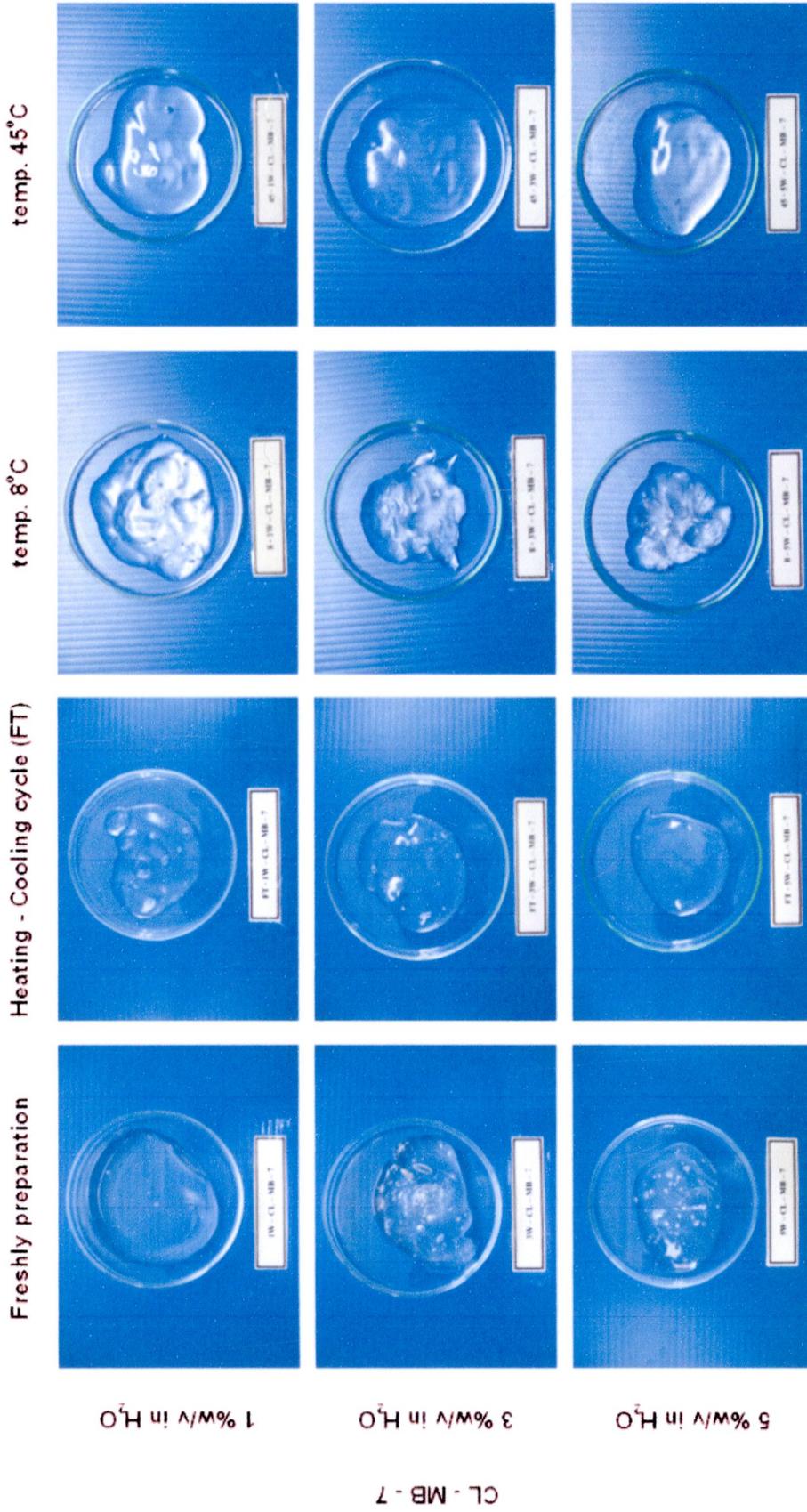


Figure 3.12F Stability of cross-linked carboxymethyl modified mungbean starch with DCA 7% (CL-MB-7) gel in H₂O

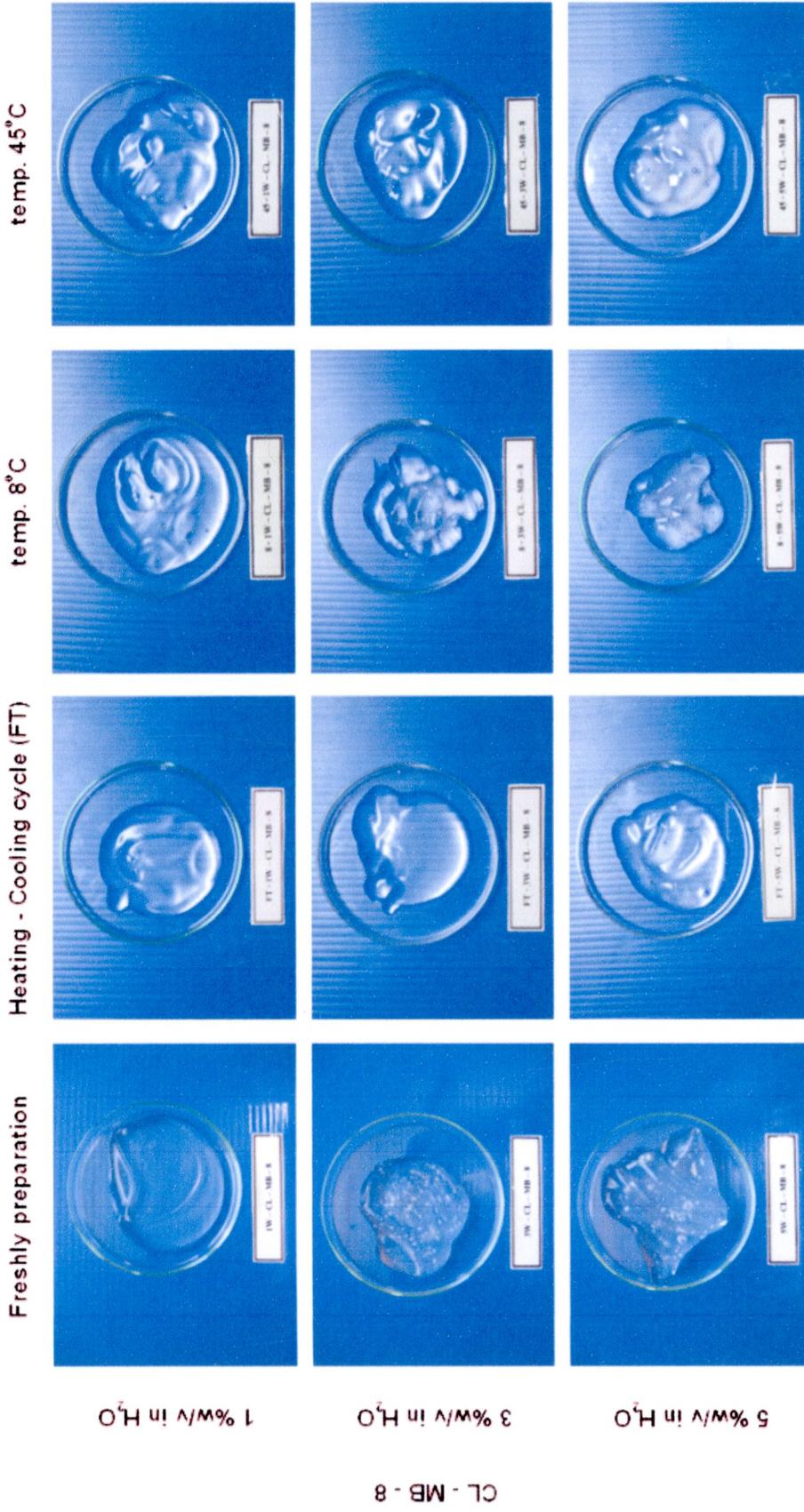


Figure 3.12G Stability of cross-linked carboxymethyl modified mungbean starch with DCA 8% (CL-MB-8) gel in H₂O

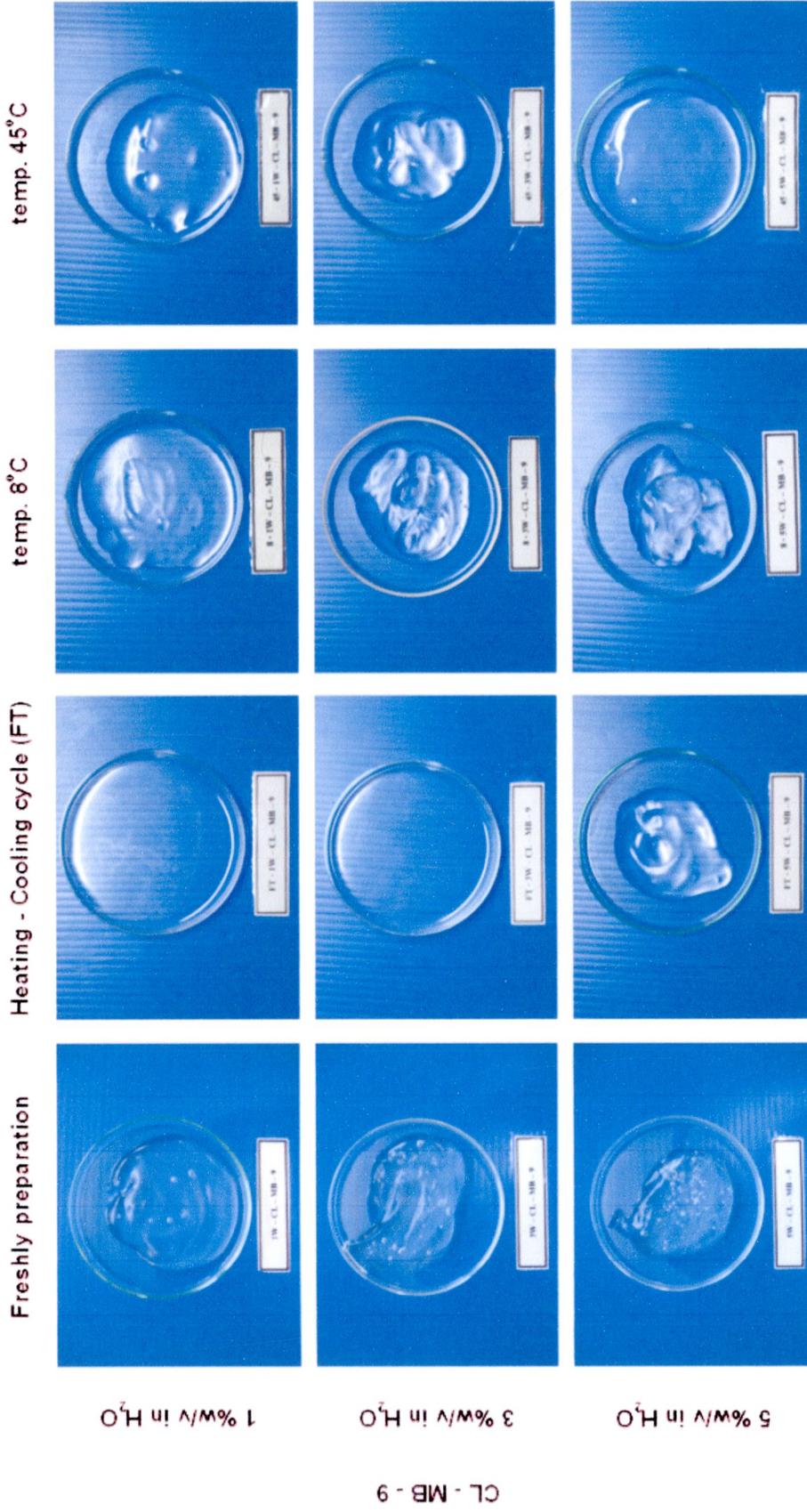


Figure 3.12H Stability of cross-linked carboxymethyl modified mungbean starch with DCA 9% (CL-MB-9) gel in H₂O

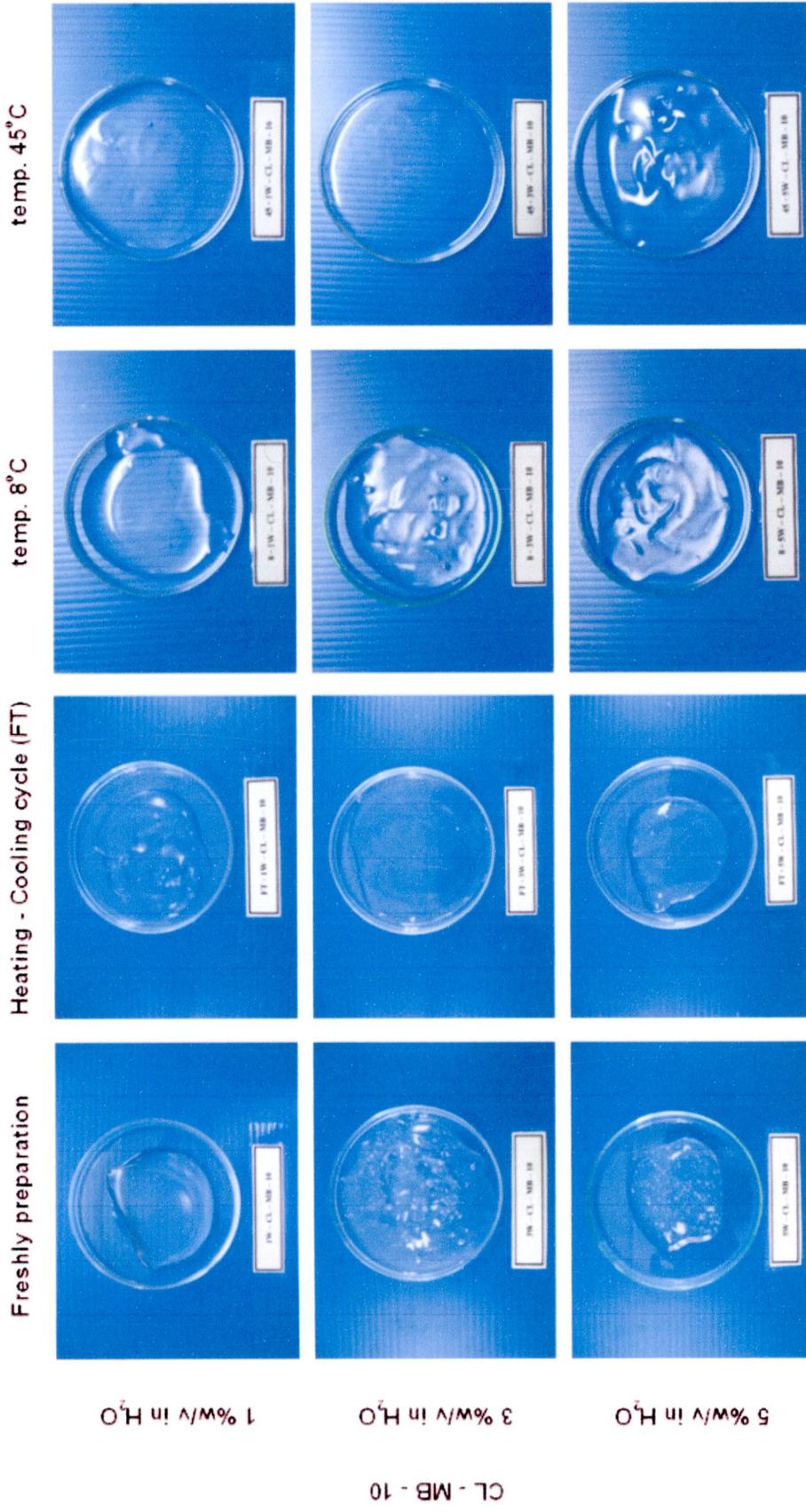


Figure 3.121 Stability of cross-linked carboxymethyl modified mungbean starch with DCA 10% (CL-MB-10) gel in H₂O

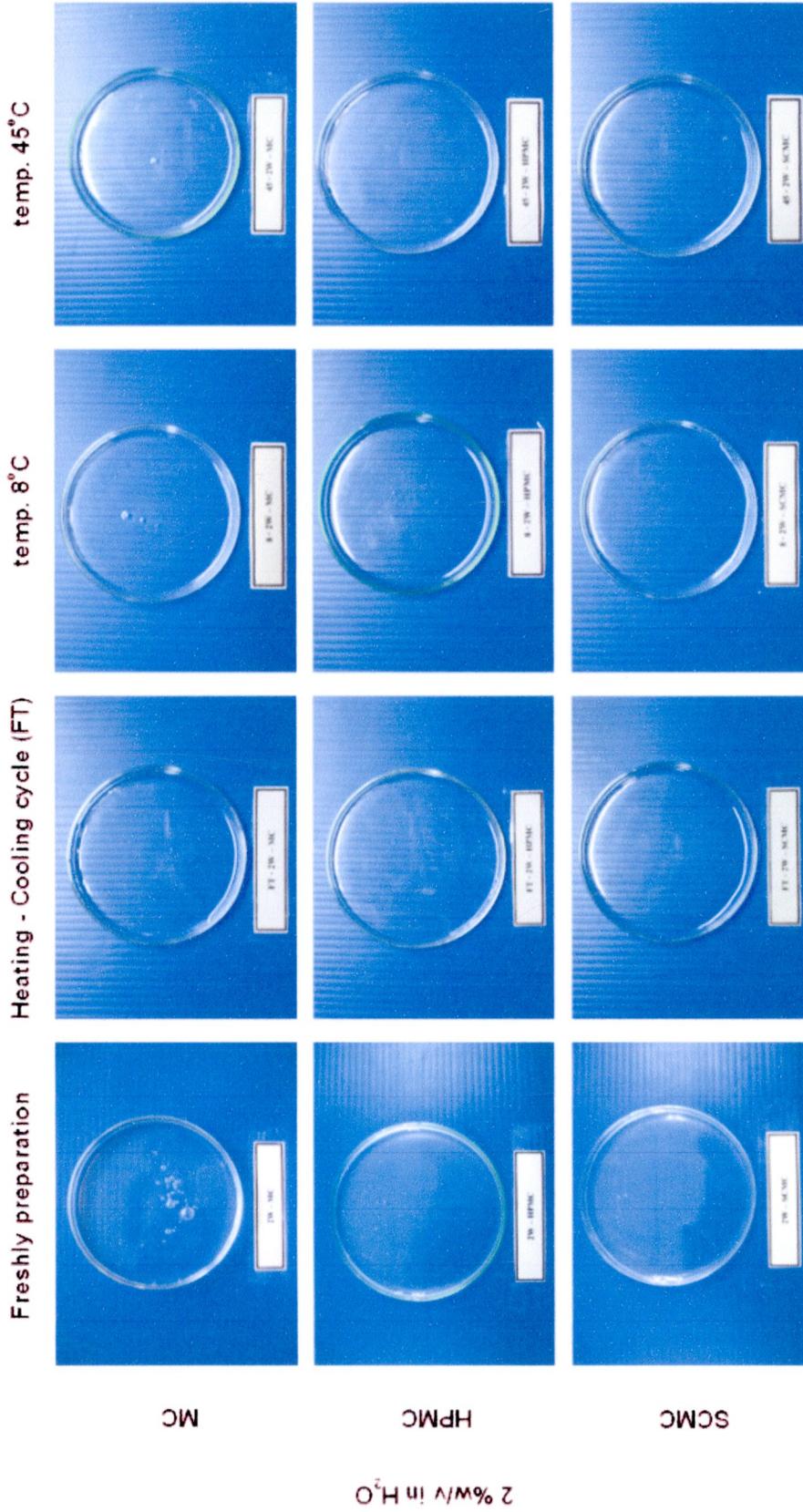


Figure 3.12J Stability of 3-commercial polymer gels (as HPMC, MC, SCMC) at 2%w/v in H₂O

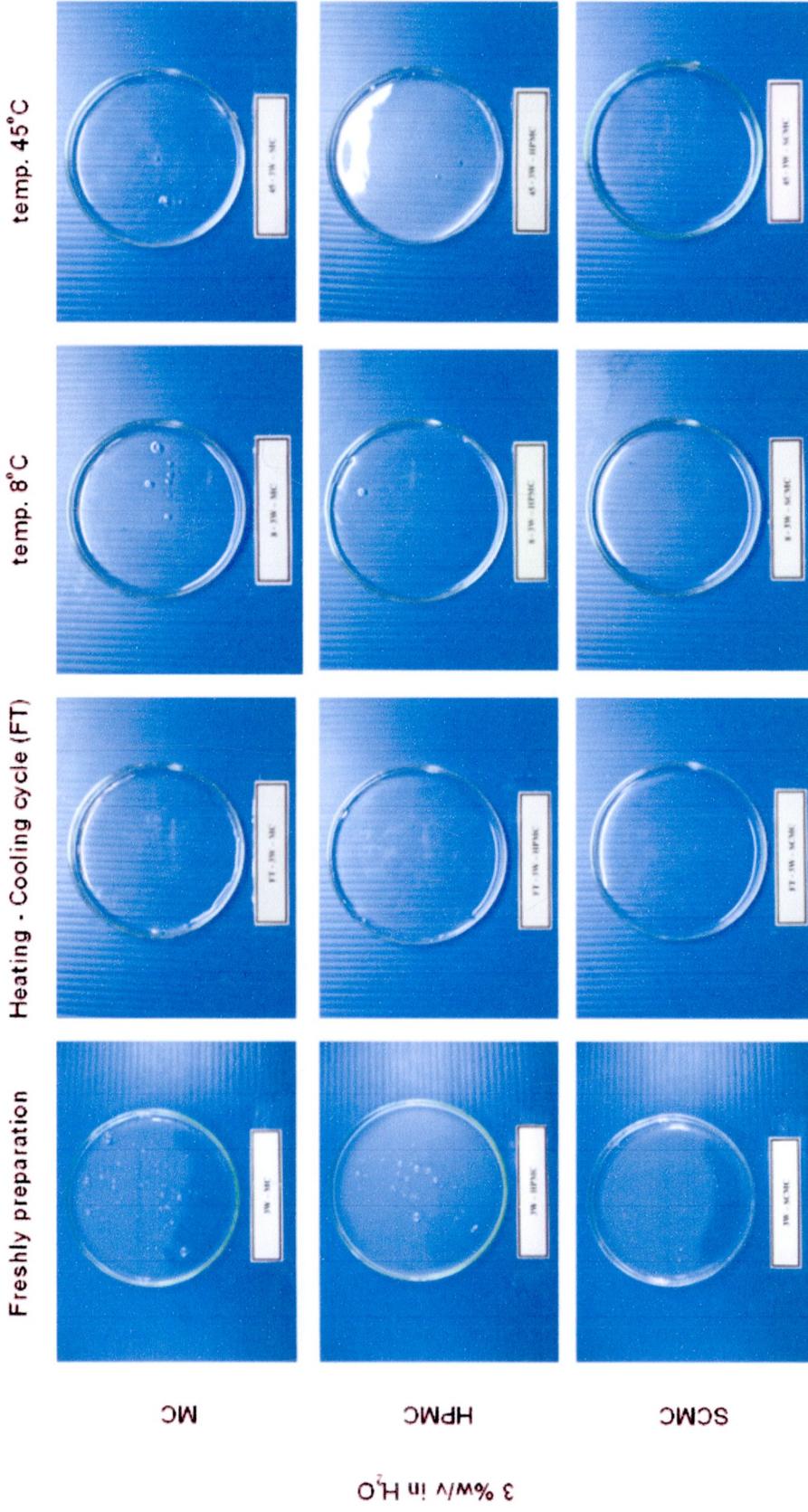


Figure 3.12K - Stability of 3-commercial polymer gels (as HPMC, MC, SCMC) at 3%w/v in H₂O

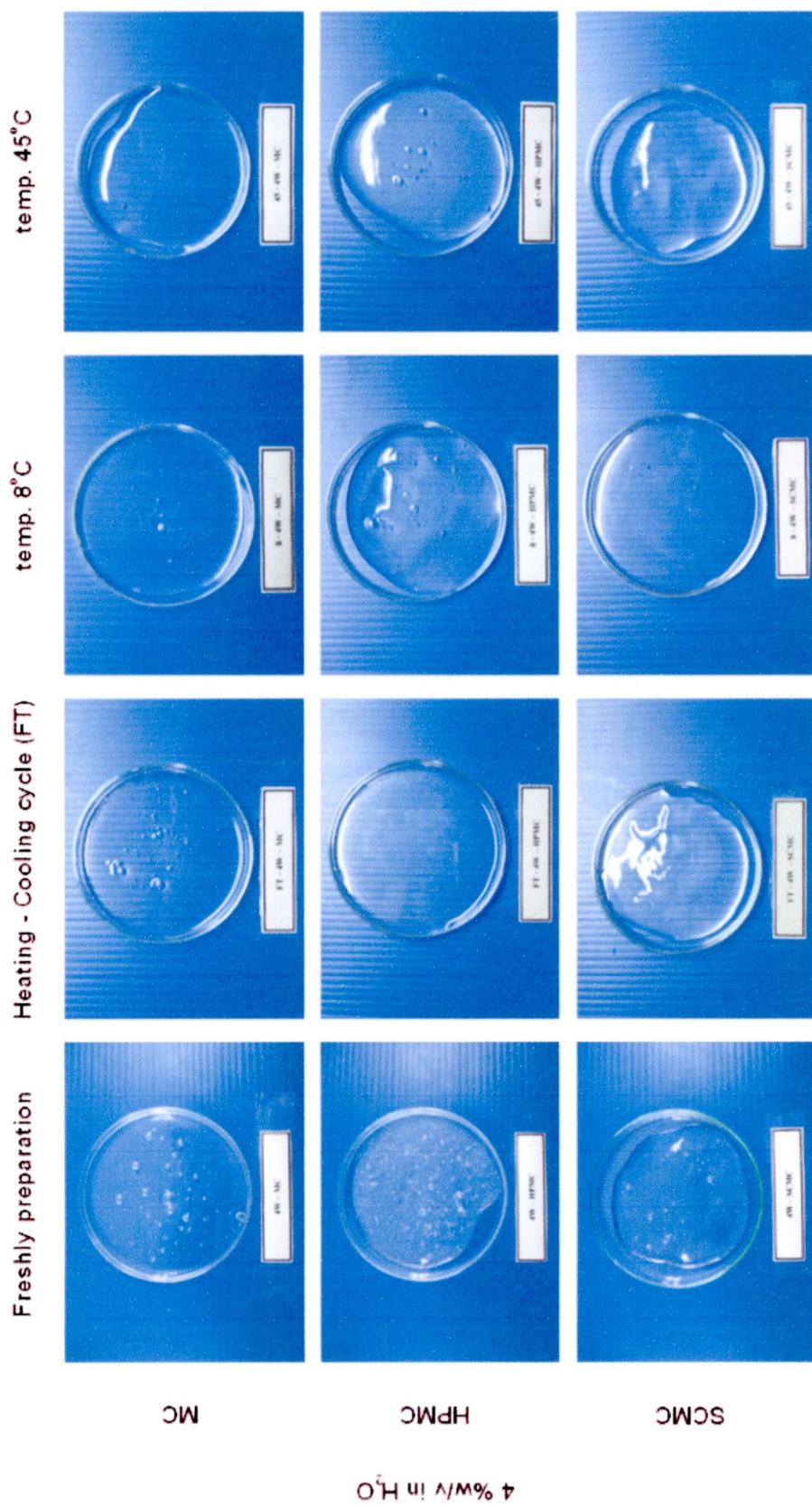


Figure 3.12L Stability of 3-commercial polymer gels (as HPMC, MC, SCMC) at 4%w/v in H₂O

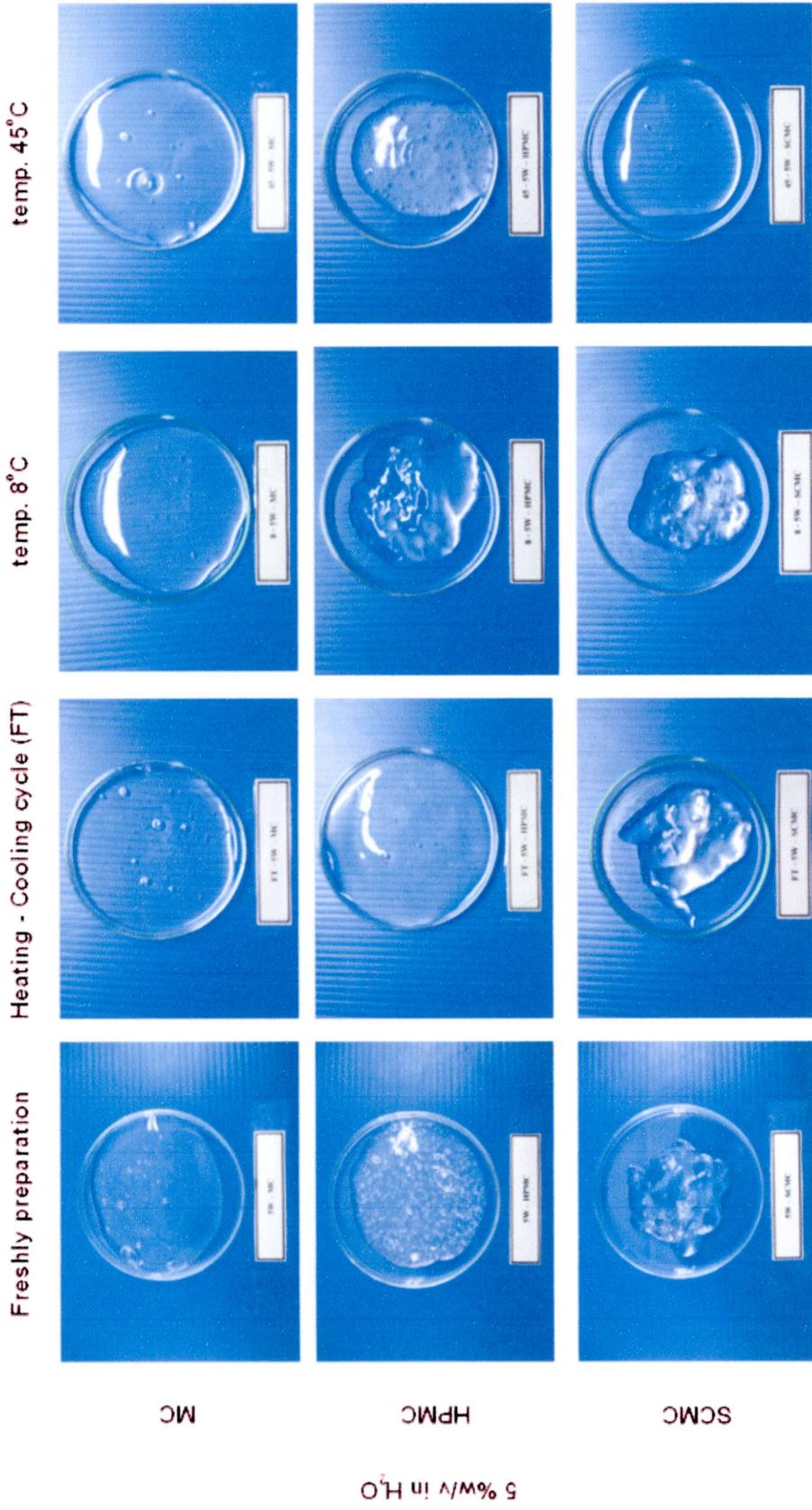


Figure 3.12M Stability of 3-commercial polymer gels (as HPMC, MC, SCMC) at 5%w/v in H₂O

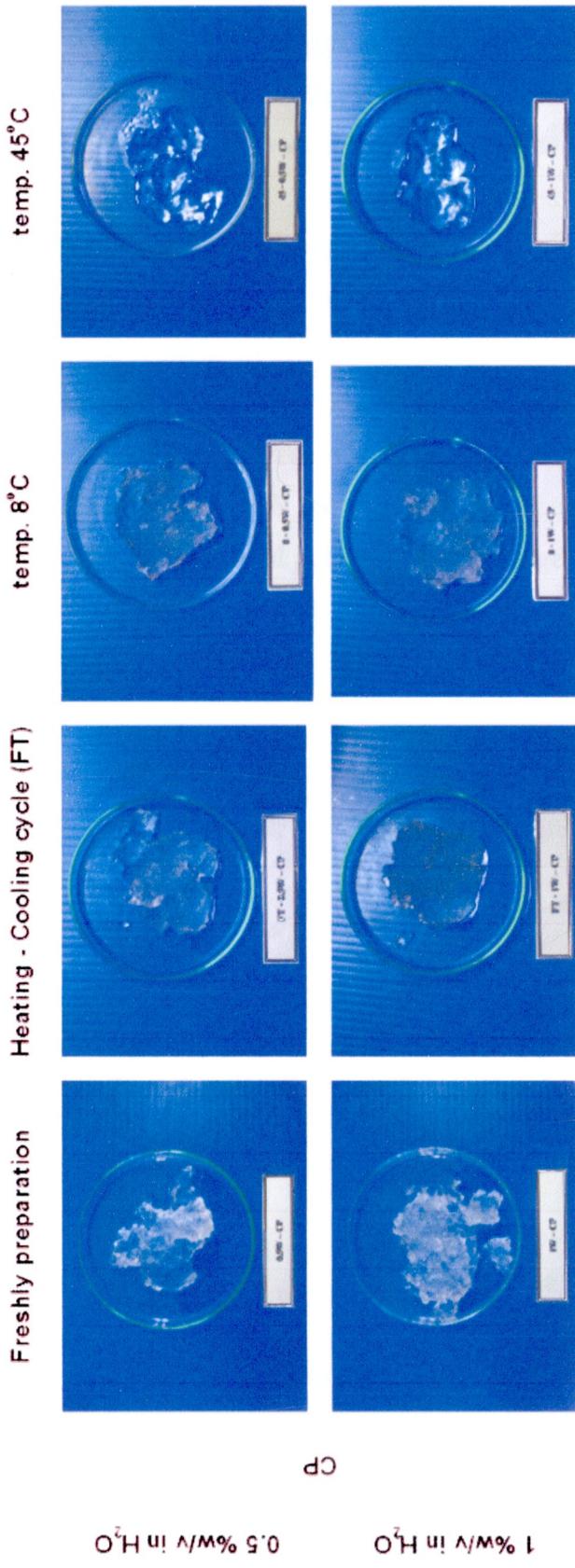


Figure 3.12N Stability of commercial polymer gel (Carbopol 940) at 0.5%w/v and 1.0%w/v in H₂O



3.4.4 Viscosity, pH and clarity of cross-linked carboxymethyl modified mungbean starch gels in distilled water

The modified starch powder was dissolved in EtOH: H₂O mix of ratio 0:100 at 1, 3 and 5%w/v concentration, compared with four commercial polymers : CP, MC, HPMC and SCMC. The gels were stored at 8°C and 45°C, and underwent a HC stability (8 cycles—each cycle consisted of 2 days at 8°C and another 2 days at 45°C), shown in Table 3.6A-3.6D.

The sample of rheograms of 7-condition CL-MBs, presented in Figure 3.13, showed a pseudoplastic flow with thixotropy; a typical behavior of a gelling agent. The rheological profile of CL-MBs showed an increase in solution viscosity compared to that of CMMS but the viscosity of CL-MBs gel was significantly less than for the four commercial polymers, but had a gel like appearance.

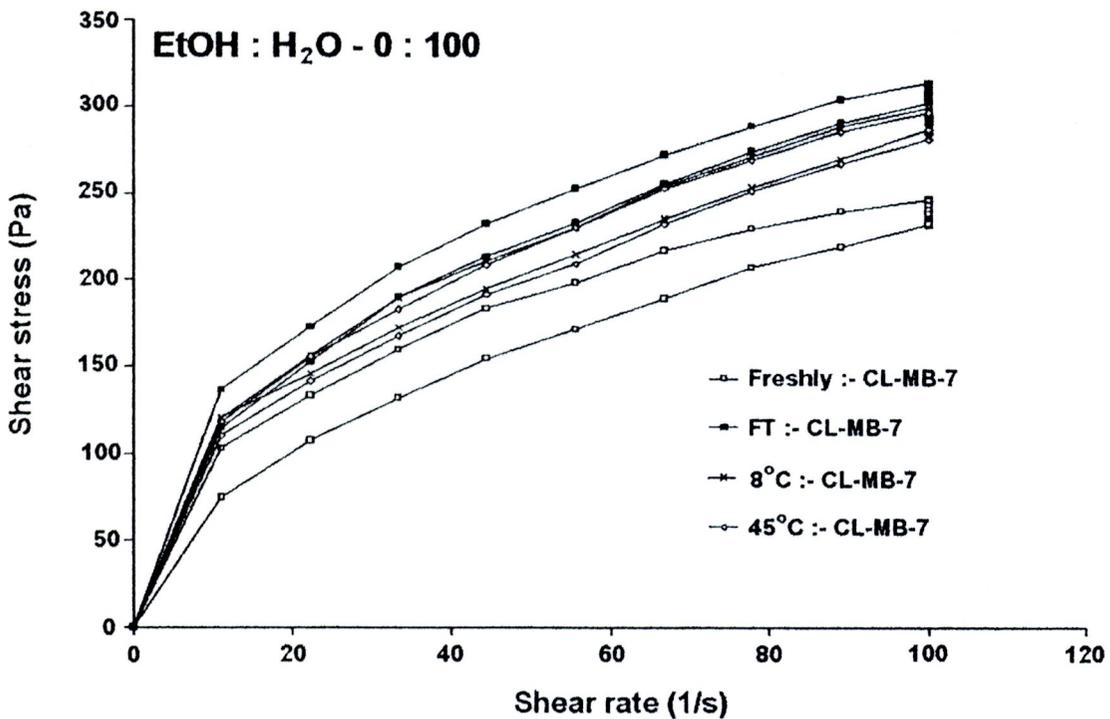


Figure 3.13 The sample of rheograms of CL-MB-7 at 1%w/v conc. in distilled water, stored in 8°C, 45°C and HC cycle stability (8 cycles—each cycle consisted of 2 days at 8°C and other 2 days at 45°C.)

Table 3.6A Viscosity, pH and Clarity of CL-MBs with varied conditions compared with CMMS and cross-linked MB at 1%w/v conc. in distilled water (H₂O)

Polymers	Freshly preparation			Heating-Cooling cycle (FT)			8°C			45°C		
	Viscosity (Pa.s)	pH	Clarity (A)	Viscosity (Pa.s)	pH	Clarity (A)	Viscosity (Pa.s)	pH	Clarity (A)	Viscosity (Pa.s)	pH	Clarity (A)
C-MB-100	1.768±0.02	7.2	0.217±0.0004	0.291±0.01	6.8	0.059±0.0000	N/A	N/A	N/A	N/A	N/A	N/A
L-MB-100	0.000	6.9	2.018±0.0025	0.000	6.9	2.071±0.0027	0.000	7.0	1.972±0.0837	0.000	6.9	1.982±0.0000
CL-MB-1	1.222±0.02	6.8	0.423±0.0004	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
CL-MB-4	1.700±0.02	6.9	0.345±0.1586	0.797±0.01	6.8	0.123±0.0004	0.461±0.01	6.9	0.064±0.0000	N/A	N/A	N/A
CL-MB-5	1.862±0.02	6.8	0.251±0.0000	1.183±0.02	6.8	0.156±0.0002	0.881±0.01	6.9	0.112±0.0000	0.529±0.01	6.8	0.090±0.0002
CL-MB-7	2.385±0.01	7.2	0.236±0.0004	2.956±0.01	7.1	0.075±0.0000	2.946±0.01	7.2	0.215±0.0000	2.947±0.05	7.0	0.162±0.0001
CL-MB-8	2.288±0.03	7.0	0.237±0.0005	1.893±0.01	6.9	0.105±0.0000	1.835±0.02	6.9	0.246±0.0000	1.339±0.01	6.8	0.166±0.0001
CL-MB-9	2.267±0.03	6.9	0.350±0.0000	1.763±0.02	6.9	0.152±0.0000	0.896±0.02	6.9	0.251±0.0000	1.658±0.01	6.8	0.183±0.0000
CL-MB-10	2.253±0.01	6.9	0.396±0.0004	1.757±0.02	6.9	0.341±0.0010	1.426±0.02	6.8	0.189±0.0000	1.261±0.02	6.9	0.323±0.0001

1 % w/v in H₂O

Table 3.6B Viscosity, pH and Clarity of CL-MBs with varied conditions compared with CMMS and cross-linked MB at 3%w/v conc. in distilled water (H₂O)

Polymers	Freshly preparation		Heating-Cooling cycle (FT)		8°C		45°C		
	Viscosity (Pa.s)	pH	Clarity (A)	Viscosity (Pa.s)	pH	Clarity (A)	Viscosity (Pa.s)	pH	Clarity (A)
3 % w/v in H₂O									
C-MB-100	3.055±0.02	7.1	0.619±0.0000	0.243±0.01	6.8	0.064±0.0004	N/A	N/A	N/A
L-MB-100	0.000	6.9	2.981±0.0071	0.000	6.9	3.042±0.0133	0.000	7.0	2.967±0.0012
CL-MB-1	2.510±0.05	6.8	0.598±0.0000	N/A	N/A	N/A	N/A	N/A	N/A
CL-MB-4	3.589±0.07	6.9	0.595±0.0000	1.465±0.03	6.8	0.184±0.0000	0.920±0.01	6.9	0.095±0.0006
CL-MB-5	4.476±0.08	6.9	0.554±0.0000	1.741±0.01	6.9	0.252±0.0001	1.667±0.03	6.9	0.098±0.0003
CL-MB-7	6.962±0.07	7.2	0.315±0.0005	7.219±0.04	7.1	0.213±0.0001	7.985±0.03	7.2	0.105±0.0000
CL-MB-8	6.481±0.05	7.1	0.437±0.0004	6.314±0.03	7.0	0.225±0.0000	7.295±0.03	6.9	0.115±0.0000
CL-MB-9	5.789±0.10	7.0	0.546±0.0000	1.665±0.02	7.0	0.258±0.0040	5.111±0.01	6.9	0.152±0.0000
CL-MB-10	5.042±0.02	7.0	0.578±0.0000	4.937±0.01	6.8	0.492±0.0004	4.875±0.01	6.8	0.485±0.0005
							1.377±0.02	7.2	0.272±0.0303
							N/A	N/A	N/A
							1.522±0.02	7.0	0.188±0.0003
							7.591±0.03	7.0	0.173±0.0000
							6.328±0.06	6.8	0.183±0.0360
							4.732±0.02	6.8	0.189±0.0000
							1.226±0.02	6.9	0.191±0.0000

Table 3.6C Viscosity, pH and Clarity of CL-MBs with varied conditions compared with CMMS and cross-linked MB at 5%w/v conc. in distilled water (H₂O)

Polymers	Freshly preparation			Heating–Cooling cycle (FT)			8°C			45°C		
	Viscosity (Pa.s)	pH	Clarity (A)	Viscosity (Pa.s)	pH	Clarity (A)	Viscosity (Pa.s)	pH	Clarity (A)	Viscosity (Pa.s)	pH	Clarity (A)
5 % w/v in H₂O												
C-MB-100	6.554±0.11	7.1	1.146±0.0005	1.599±0.02	6.9	0.829±0.0005	N/A	N/A	N/A	N/A	N/A	N/A
L-MB-100	0.000	7.0	3.049±0.0085	0.000	6.9	3.082±0.0115	0.000	7.0	2.911±0.0000	0.000	7.0	2.975±0.0003
CL-MB-1	3.128±0.16	6.9	0.844±0.0005	0.358±0.01	7.0	0.475±0.0000	N/A	N/A	N/A	N/A	N/A	N/A
CL-MB-4	5.225±0.03	6.8	0.818±0.0005	3.216±0.03	6.9	0.704±0.0000	0.211±0.01	6.9	0.220±0.0000	N/A	N/A	N/A
CL-MB-5	6.280±0.05	6.8	0.807±0.0005	3.493±0.01	6.9	0.726±0.0000	6.228±0.02	7.0	0.134±0.0001	4.531±0.07	7.1	0.488±0.0010
CL-MB-7	10.023±0.02	7.1	0.424±0.0004	7.430±0.06	7.2	0.423±0.0001	8.363±0.06	7.2	0.112±0.0000	8.359±0.08	7.1	0.439±0.0001
CL-MB-8	9.706±0.02	7.0	0.493±0.0000	8.644±0.09	7.0	0.485±0.0004	7.425±0.02	6.9	0.116±0.0004	7.235±0.03	7.0	0.442±0.0000
CL-MB-9	9.579±0.18	6.9	0.634±0.0007	9.131±0.01	7.1	0.603±0.0048	9.385±0.05	7.0	0.644±0.0002	6.665±0.08	6.9	0.465±0.0003
CL-MB-10	7.568±0.10	6.9	0.831±0.0004	7.609±0.06	7.0	0.690±0.0005	7.228±0.02	7.2	0.572±0.0000	4.653±0.03	6.9	0.634±0.0029

Table 3.6D Viscosity, pH and Clarity of 4-commercial polymers : CP, MC, HPMC and SCMC at varied concentration in distilled water (H₂O)

Polymers	Freshly preparation		Heating–Cooling cycle (FT)		8°C		45°C					
	Viscosity (Pa.s)	pH (A)	Viscosity (Pa.s)	Clarity (A)	Viscosity (Pa.s)	pH (A)	Viscosity (Pa.s)	Clarity (A)				
0.5 % w/v in H₂O												
CP	12.995±0.18	7.4	0.053±0.0004	12.416±0.016	7.5	0.061±0.0000	12.825±0.11	7.4	0.102±0.0000	5.727±0.11	7.4	0.061±0.0000
1.0 % w/v in H₂O												
CP	13.304±0.24	7.5	0.445±0.0004	14.827±0.030	7.4	0.445±0.0004	15.818±0.29	7.4	0.189±0.0000	8.384±0.11	7.4	0.209±0.0000
2 % w/v in H₂O												
MC	2.964±0.04	6.9	0.016±0.0000	2.762±0.03	7.0	0.009±0.0002	2.658±0.02	7.1	0.008±0.0000	2.709±0.02	6.9	0.015±0.0000
HPMC	2.003±0.03	6.8	0.128±0.0004	2.848 ±0.05	7.0	0.015±0.0000	2.733±0.03	6.8	0.019±0.0001	1.938±0.09	7.1	0.038±0.0001
SCMC	2.416±0.02	6.9	0.022±0.0000	1.983±0.02	6.9	0.012±0.0000	1.570±0.02	7.1	0.014±0.0001	1.851±0.03	6.9	0.025±0.0000

Table 3.6D(cont.) Viscosity, pH and Clarity of 4-commercial polymers : CP, MC, HPMC and SCMC at varied concentration in distilled water (H₂O)

Polymers	Freshly preparation		Heating–Cooling cycle (FT)		8°C		45°C	
	Viscosity (Pa.s)	pH (A)	Viscosity (Pa.s)	pH (A)	Viscosity (Pa.s)	pH (A)	Viscosity (Pa.s)	pH (A)
3 % w/v in H₂O								
MC	6.701±0.13	6.8	7.528±0.02	7.0	6.519±0.05	6.9	6.493±0.07	7.0
HPMC	5.074±0.04	6.7	7.423±0.11	6.9	7.411±0.12	6.9	4.260±0.04	6.7
SCMC	4.175±0.05	6.8	3.604±0.04	6.7	1.911±0.04	6.9	3.587±0.01	7.0
4 % w/v in H₂O								
MC	12.034±0.16	7.0	11.696±0.18	6.9	11.809±0.06	7.1	11.899±0.21	7.0
HPMC	10.482±0.16	6.8	10.173±0.12	7.0	12.391±0.14	6.9	12.126±0.05	6.9
SCMC	9.476±0.09	6.8	8.067±0.15	7.1	6.389±0.12	7.0	8.634±0.23	6.9
5 % w/v in H₂O								
MC	16.903±0.15	7.1	17.499±0.06	7.0	17.971±0.17	7.0	14.358±0.05	6.9
HPMC	13.616±0.28	7.2	12.287±0.25	7.1	14.000±0.23	7.0	14.620±0.27	7.1
SCMC	12.935±0.07	6.9	11.944±0.10	6.8	10.329±0.08	6.9	11.366±0.08	7.0

MC	0.021±0.0000	0.035±0.0000
HPMC	0.043±0.0000	0.084±0.0001
SCMC	0.026±0.0000	0.058±0.0000

In table 3.6A, the viscosity of CL-MB-5, CL-MB-7, CL-MB-8, CL-MB-9 and CL-MB-10 gel were significantly higher than CMMS (1.768 ± 0.02 Pa.s) at 1%w/v concentration in distilled water. The CL-MB-7 exhibited the highest viscosity (2.385 ± 0.01 Pa.s). The viscosity was increased at the high concentration. Under accelerated conditions, the characteristics of CL-MBs gel were not different from those of CMMS gel. The viscosity of CL-MBs solutions after being subjected to HC cycles remained two times higher than that of CMMS at the same concentration. The viscosity of CL-MB gel was significantly less than for the four commercial polymers, but had a gel-like appearance. The CL-MBs gels that exhibited good viscosity were CL-MB-7 and CL-MB-8, because the values were only slightly changed after the stability test at 8°C and 45°C , after the HC cycle stability test (not significant).

The pH of CL-MBs gels at 1, 3 and 5%w/v in the distilled water was 6.8 to 7.4, unchanged from the pH of CMMS gels at the same condition ($\text{pH} = 7.2$) These was nearby the pH of 3-commercial polymers : MC, HPMC and SCMC, excepted CP that had 7.4-7.5 because the TEA was added.

The clarities of CL-MBs gel at 700 nm, presented in Table 3.6A-3.6D, were more than that of CMMS at the same condition; although the gel is turbid at high concentrations. The clarity of CL-MB-7 gel in distilled water was significantly less than for the four commercial polymers, but similar to CMMS, and slightly changed at 8°C and 45°C and when tested for HC cycle stability. The clarity of CL-MBs decreased at high concentrations, similar to CMMS. The CL-MBs gels that exhibited the best clarity were CL-MB-7, CL-MB-8 and CL-MB-9. Their clarity changed slightly after a stability test at 8°C and 45°C , and an HC cycle stability (not significant). The cross-linked MB showed a very high absorbance level, because it is insoluble in water. However, the clarity of the CL-MBs gels was better than for the CMMS gel.

3.4.5 Viscosity of cross-linked carboxymethyl modified mungbean starch gels at varies pH

Table 3.7, the viscosity of CL-MBs exhibited the highest viscosity at pH 5.4. CL-MB-7, CL-MB-8, CL-MB-9 and CL-MB-10 viscosity were significantly higher than that of CMMS at varied pH. The viscosity decreased at the high acid and

base conditions. So, the suitable pH interval that had slightly changed values and a gel-like appearance was 4.4-7.0.

Table 3.7 Viscosity of Cross-linked carboxymethyl modified mungbean starch at varies pH compared with CMMS

pH	Viscosity (Pa.s)							
	CMMS	CL-MB-1	CL-MB-4	CL-MB-5	CL-MB-7	CL-MB-8	CL-MB-9	CL-MB-10
2.4	0.452±0.02	0.387±0.01	0.359±0.09	0.498±0.02	0.517±0.02	0.653±0.05	0.706±0.08	0.708±0.03
3.4	0.691±0.01	0.410±0.09	0.623±0.01	0.599±0.04	0.641±0.05	1.102±0.03	1.082±0.03	0.985±0.07
4.4	0.724±0.05	0.430±0.06	0.678±0.04	0.772±0.02	1.382±0.03	1.523±0.05	1.515±0.03	1.195±0.02
5.4	0.841±0.02	0.468±0.03	0.930±0.06	0.889±0.02	1.391±0.04	1.536±0.04	1.832±0.03	1.413±0.06
6.4	0.526±0.01	0.445±0.02	0.763±0.02	0.722±0.02	1.124±0.03	1.138±0.02	1.307±0.02	1.408±0.03
7.0	0.419±0.06	0.426±0.08	0.721±0.02	0.458±0.04	0.693±0.03	1.054±0.03	1.204±0.02	1.088±0.06
7.4	0.299±0.01	0.398±0.08	0.391±0.03	0.354±0.02	0.451±0.02	0.426±0.07	0.539±0.06	0.504±0.05
8.0	0.219±0.01	0.384±0.08	0.326±0.12	0.295±0.03	0.438±0.09	0.427±0.03	0.325±0.02	0.443±0.01
9.4	0.212±0.08	0.211±0.05	0.306±0.07	0.293±0.06	0.233±0.05	0.285±0.09	0.347±0.01	0.305±0.02
10.0	0.011±0.04	0.200±0.04	0.235±0.07	0.268±0.03	0.219±0.04	0.349±0.02	0.292±0.02	0.294±0.02

3.5 Alcohol tolerability

3.5.1 The particularities of cross-linked carboxymethyl modified mungbean starch gels in the alcohol solution

The modified starch powder was dissolved in EtOH:H₂O mix of ratio 30:70 and 50:50 at 1, 3 and 5%w/v concentration, compared with 4-commercial polymers : CP, HPMC, MC and SCMC. The gels were stored at 8°C and 45°C, and underwent a HC stability (8 cycles—each cycle consisted of 2 days at 8°C and another 2 days at 45°C), shown in Figure 3.14A-3.14N and 3.15A-3.15N. The facts were compared with the data before stability test (freshly preparation).

CL-MBs gels were prepared using the order-of-mixing technique. The CL-MBs powder was dissolved in H₂O that was specified ratio of EtOH:H₂O at 1, 3 and 5%w/v. The CL-MBs gels were allowed to stand overnight at room temperature. Then, the specified ratio of EtOH (30 or 50%v/v) was added and mixed to be homogenous gel.

In the experiment, CMMS gel attains its best properties with high concentration; though the gel is turbid at high concentrations. Another weak point of CMMS is that it is less resistant to alcohol at 30 and 50%v/v. The gel was glue-like and the viscosity became lower at the stability test with the observation. In the other hand, the clarity of CL-MBs gel was increased in the alcohol solution. The alcohol tolerability and stability of CL-MBs each condition was difference. The viscosity of CL-MB-1 was decrease and still as a gel appearance at 3 and 5%w/v concentration. The CL-MB-1 gel was unstable after the stability test. CL-MB-4 and CL-MB-5 gel were more stable than CL-MB-1 but less than CL-MB-7, CL-MB-8, CL-MB-9 and CL-MB-10. At the ratio of EtOH:H₂O 50:50, the viscosity of CL-MB-7, CL-MB-8, CL-MB-9 and CL-MB-10 became lower that contrast with 4-commercial polymers: CP, MC, HPMC and SCMC. The CL-MBs gels that exhibited good viscosity were CL-MB-7, CL-MB-8 and CL-MB-9 because they had slightly changed values after the stability test at 8°C and 45°C, after the HC cycle stability test (not significant). Therefore, CL-MB-7, CL-MB-8 and CL-MB-9 can resist up to 30%v/v EtOH and exhibited greater tolerance at high concentration. The cross-linked MB was insoluble in water and EtOH.

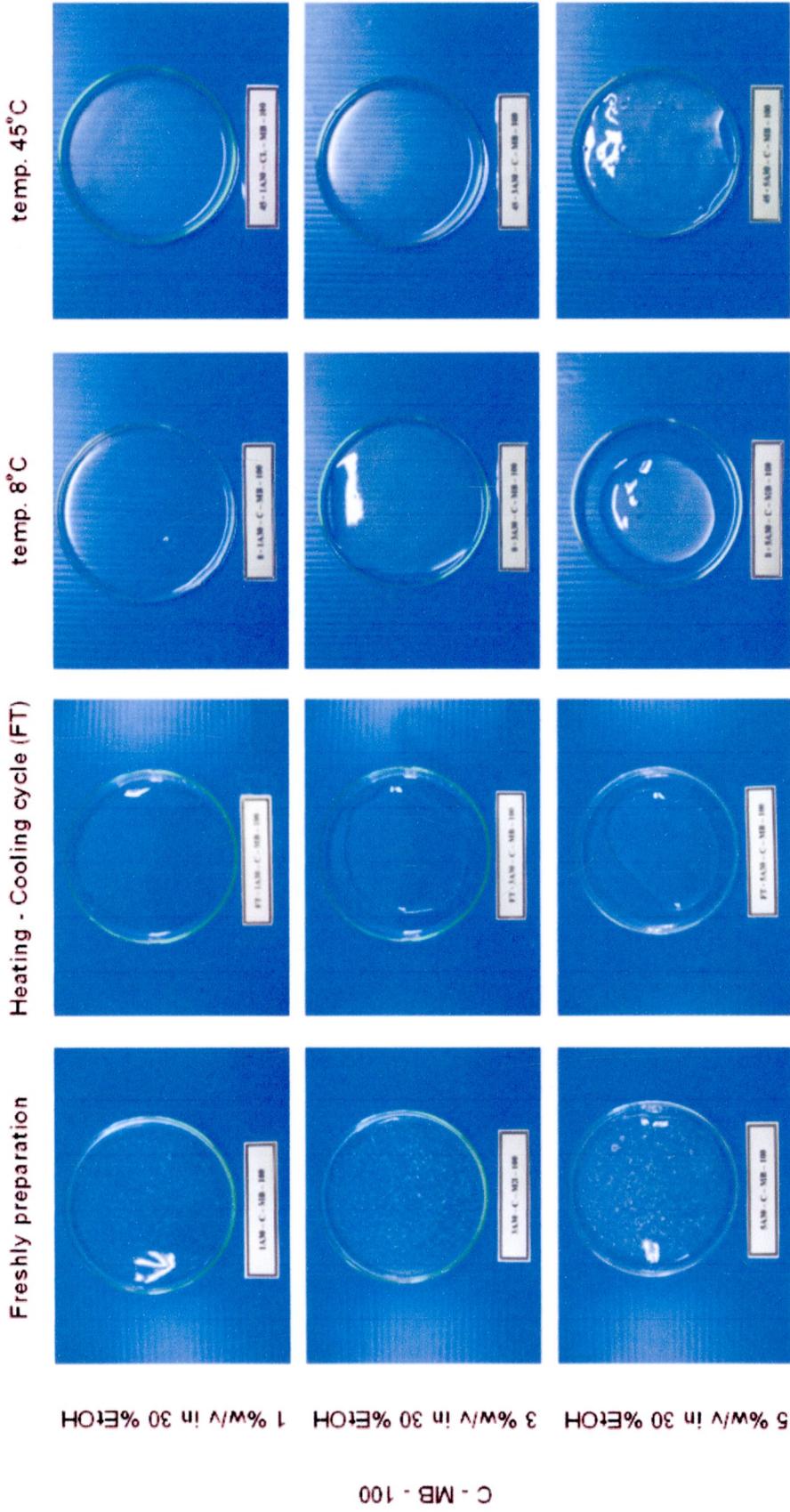


Figure 3.14A Stability of carboxymethyl modified mungbean starch (C-MB-100) gel in 30 %EtOH

C - MB - 100

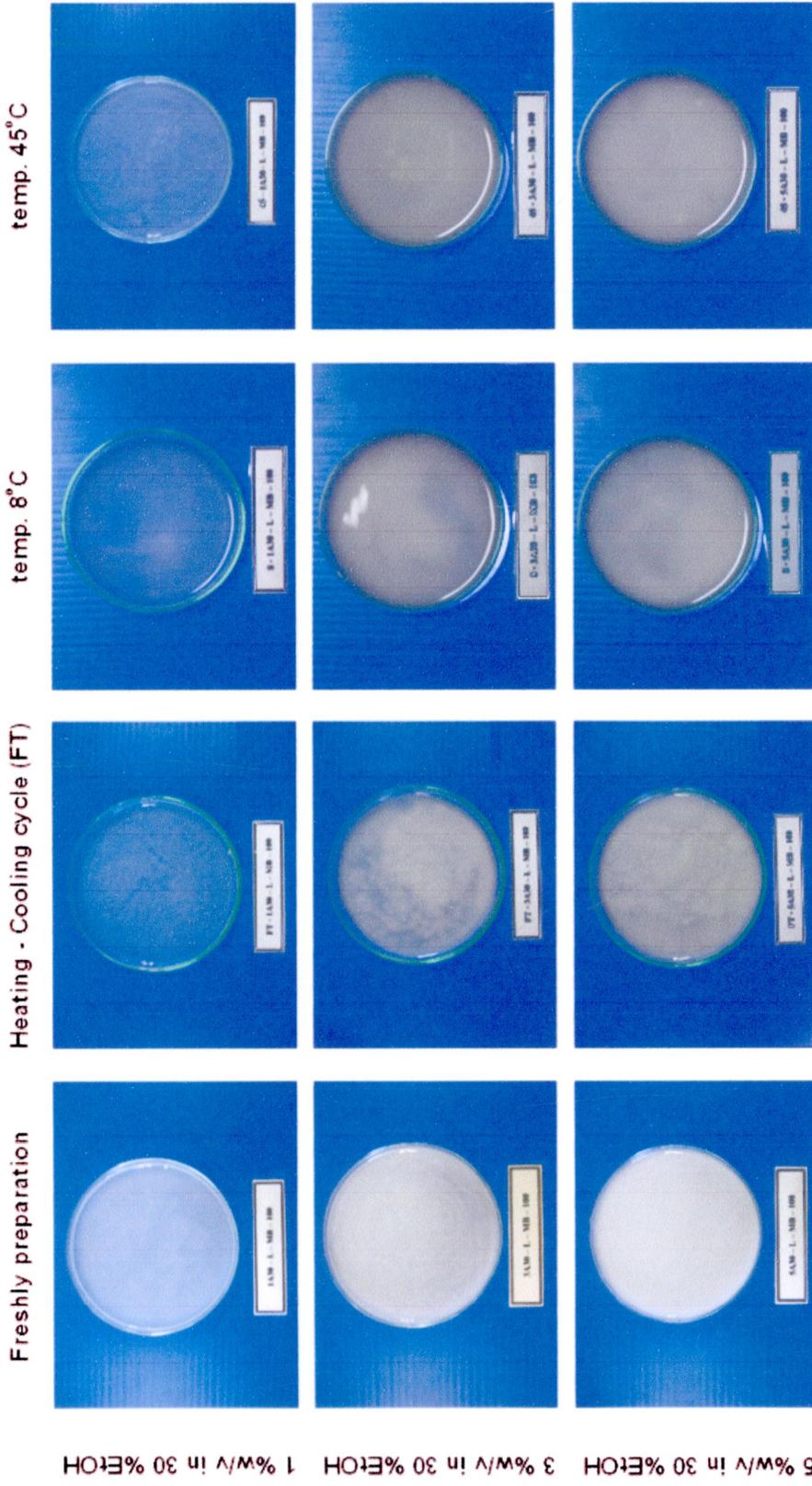
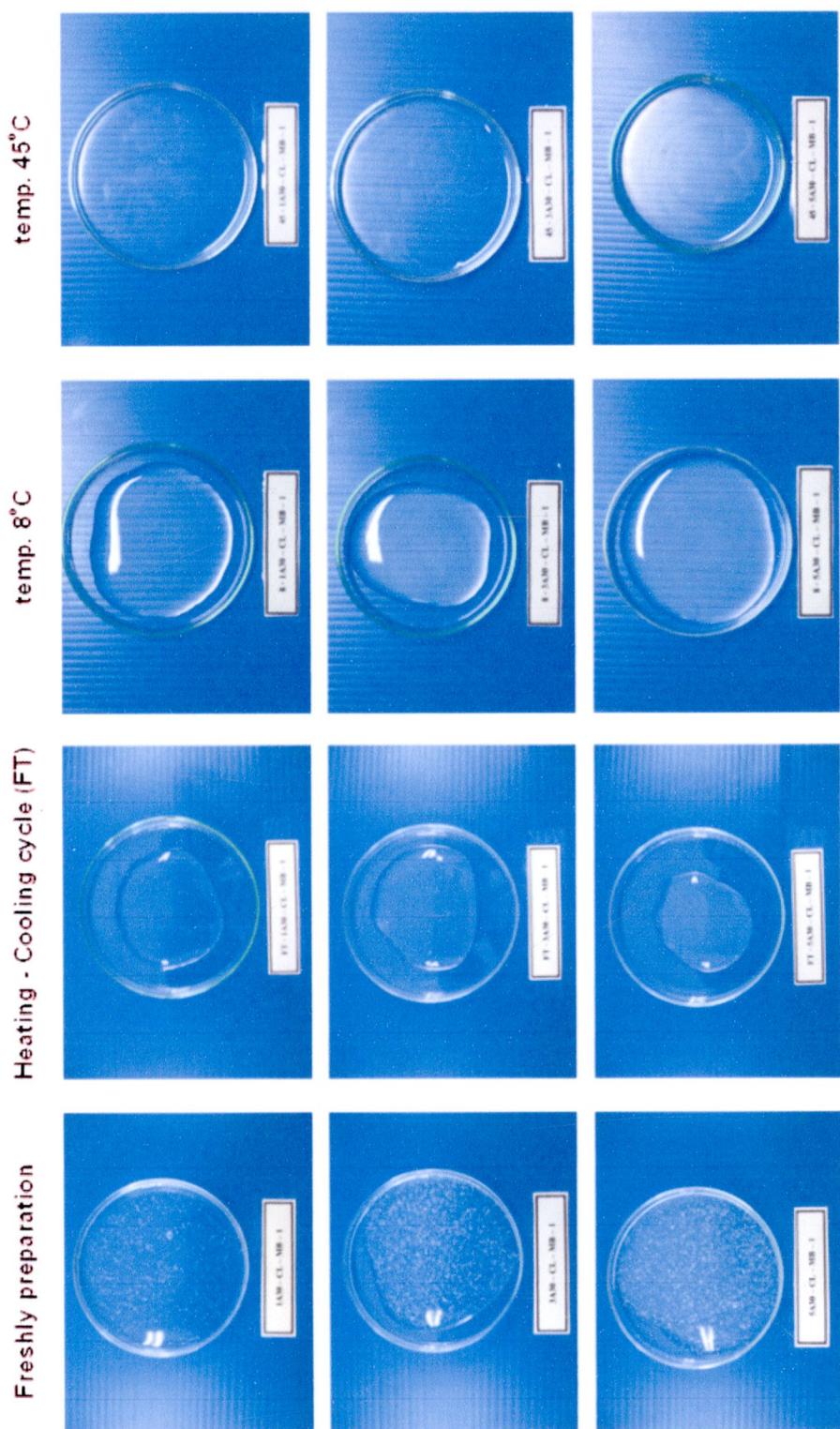


Figure 3.14B Stability of cross-linked modified mungbean starch (L-MB-100) suspension in 30 %EtOH

L - MB - 100



CL - MB - 1

Figure 3.14C Stability of cross-linked carboxymethyl modified mungbean starch with DCA 1% (CL-MB-1) gel in 30%EtOH

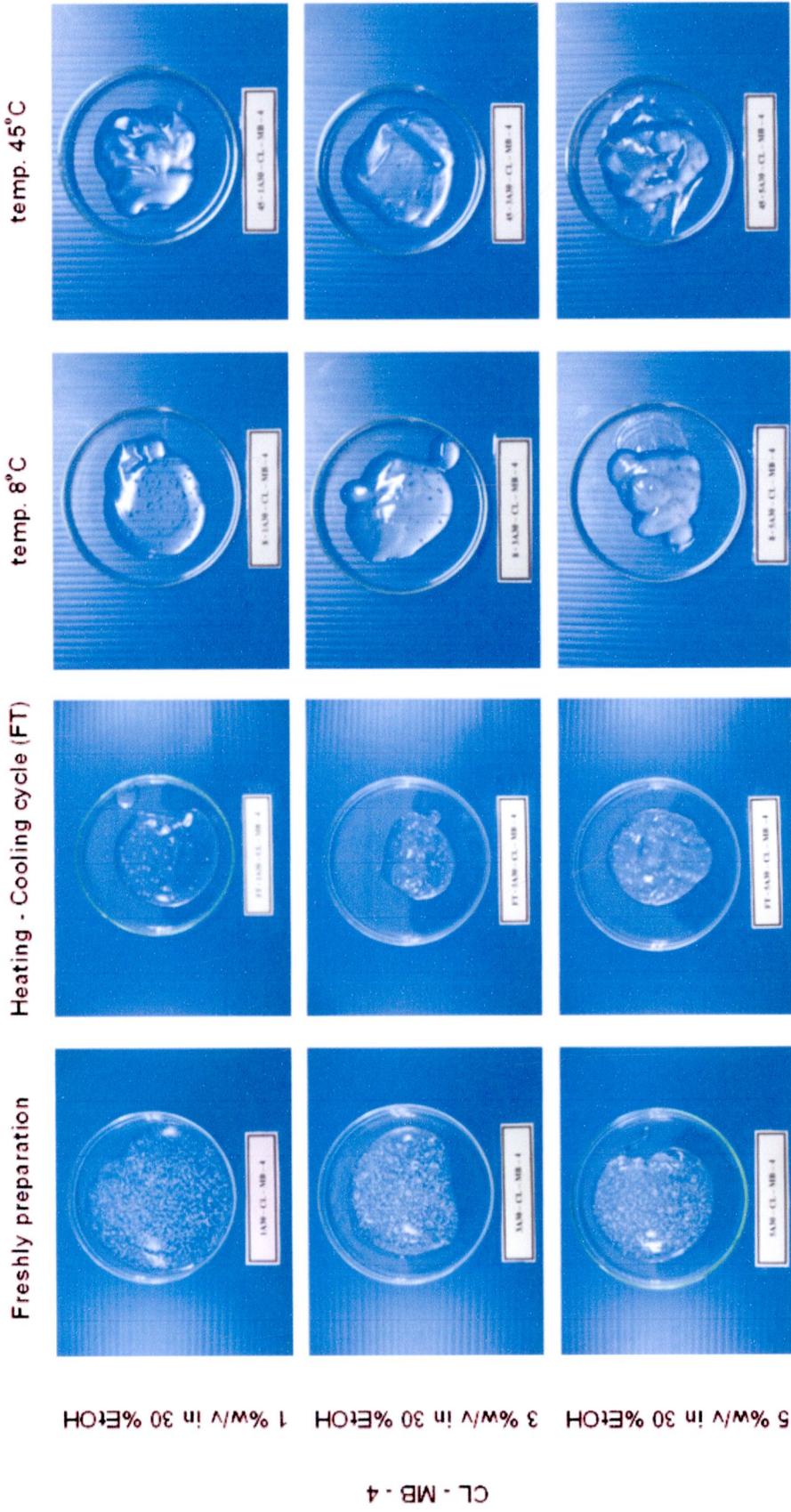


Figure 3.14D Stability of cross-linked carboxymethyl modified mungbean starch with DCA 4% (CL-MB-4) gel in 30 %EtOH

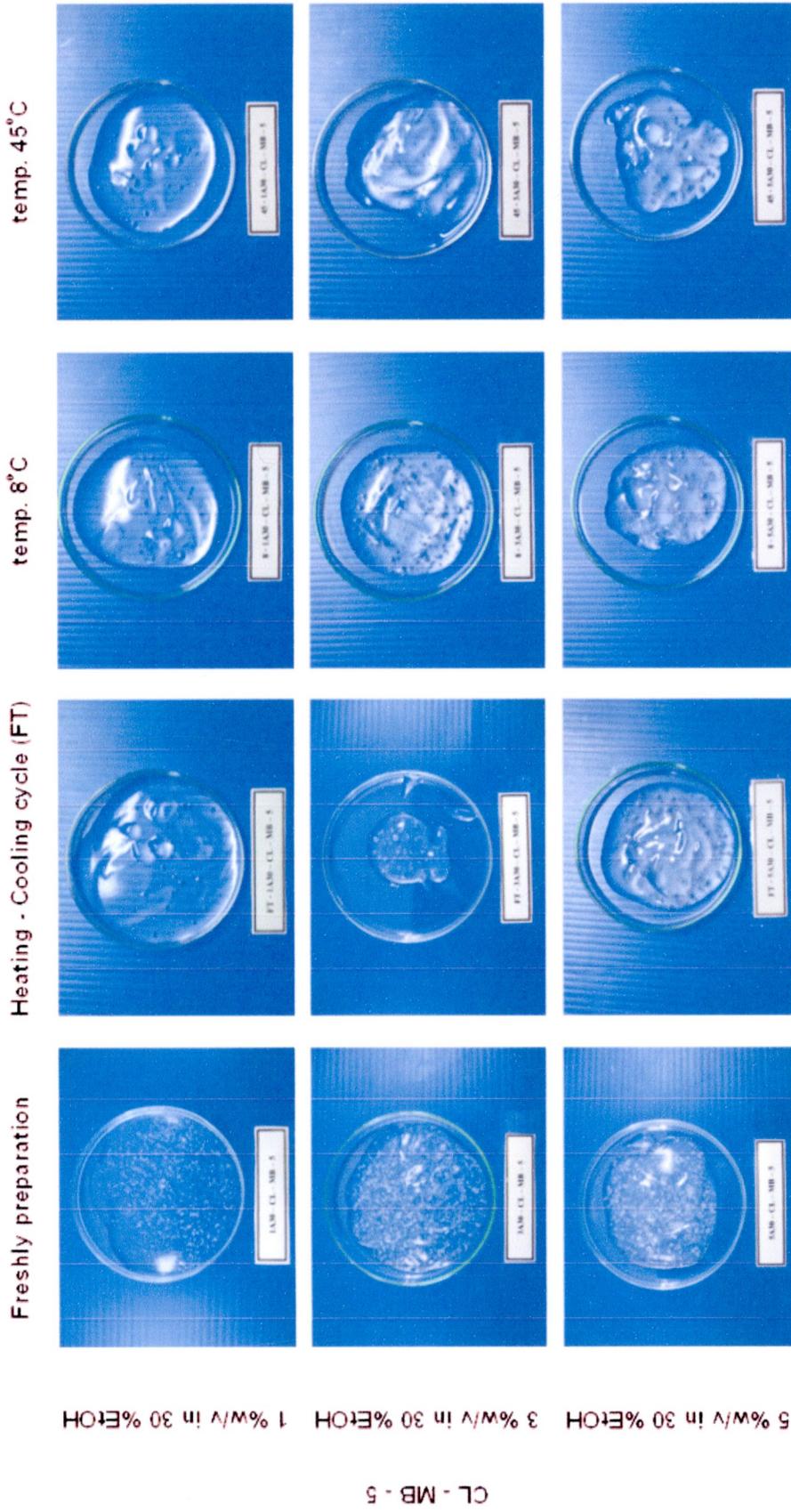


Figure 3.14E Stability of cross-linked carboxymethyl modified mungbean starch with DCA 5% (CL-MB-5) gel in 30 %EtOH

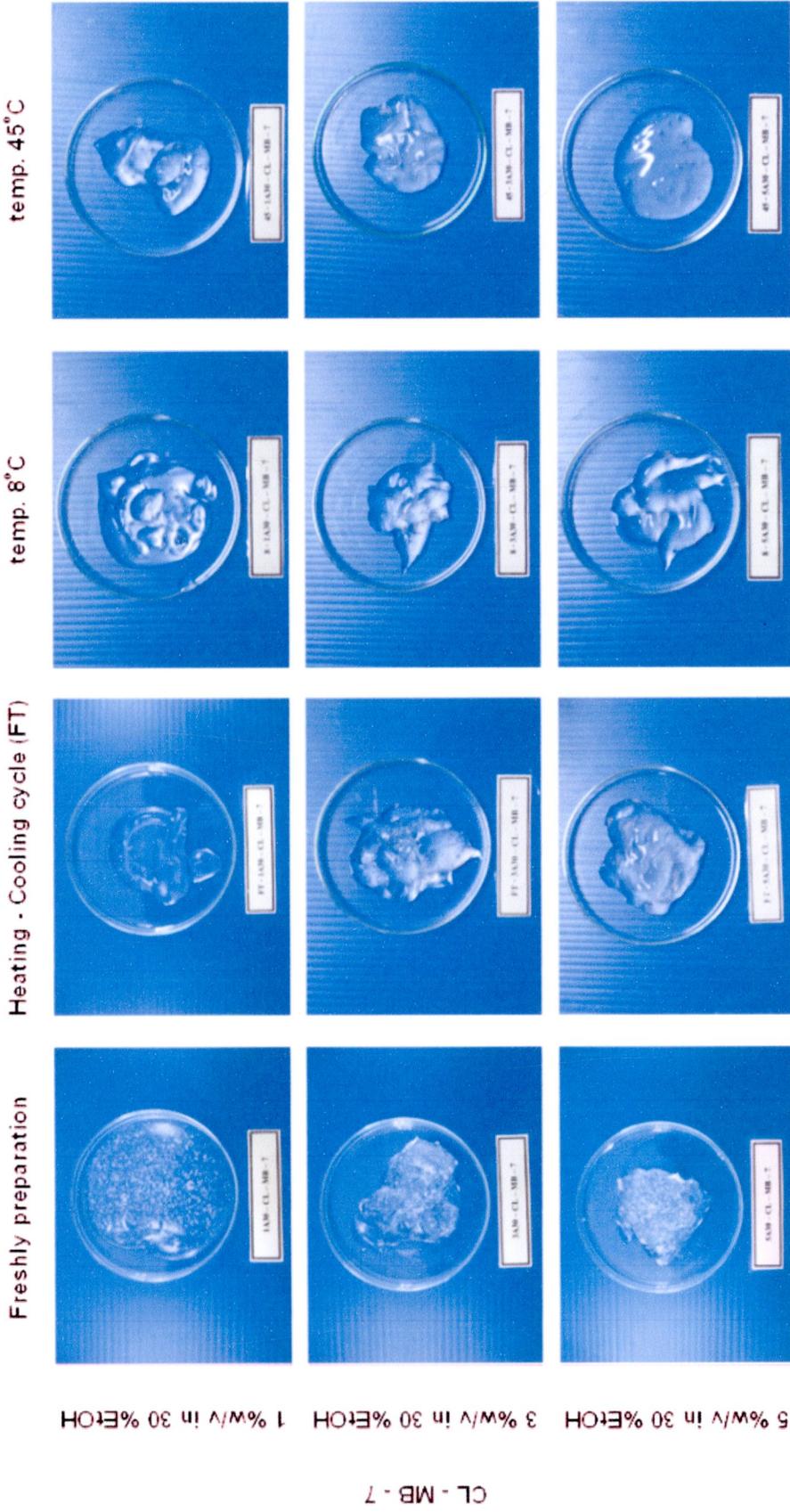
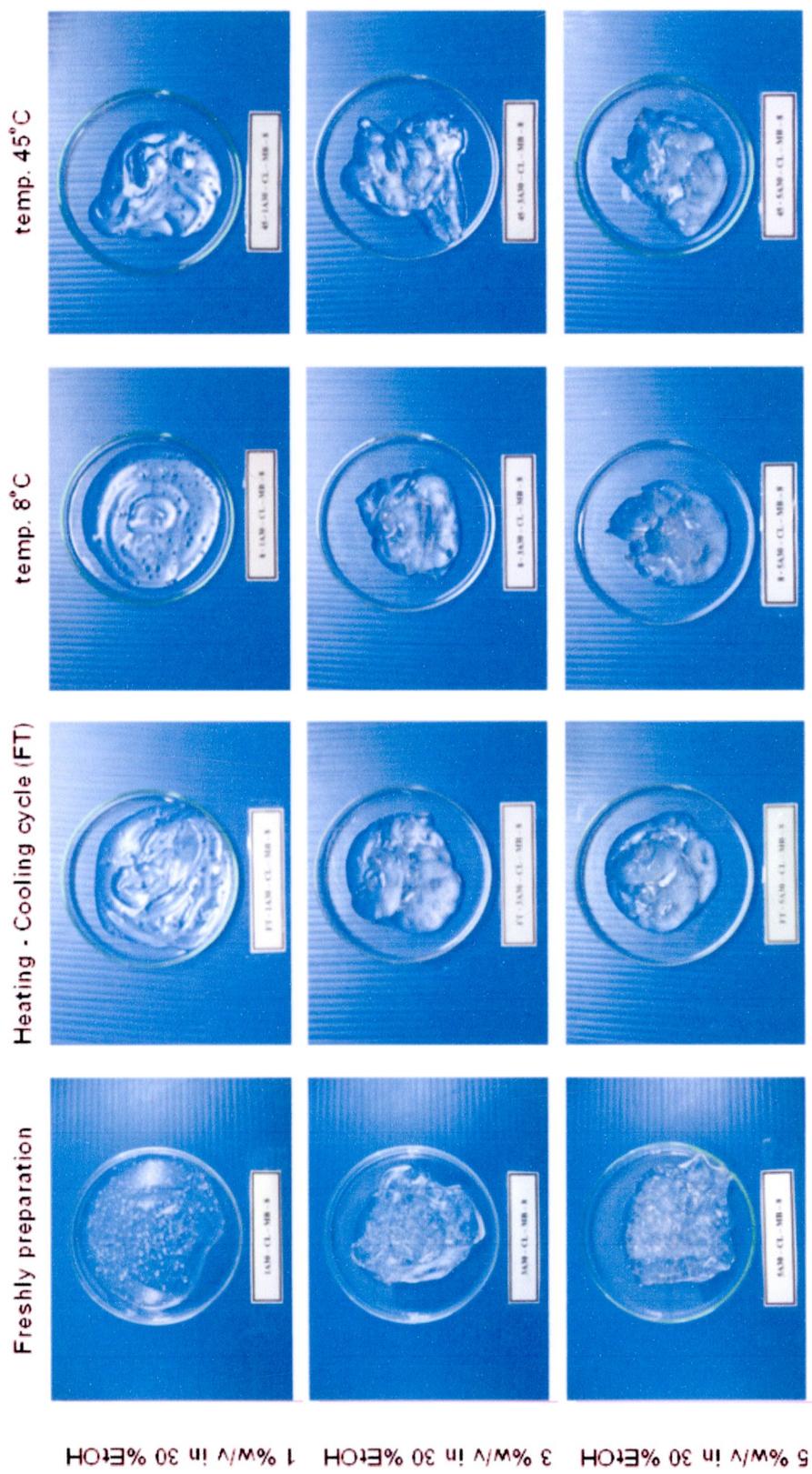
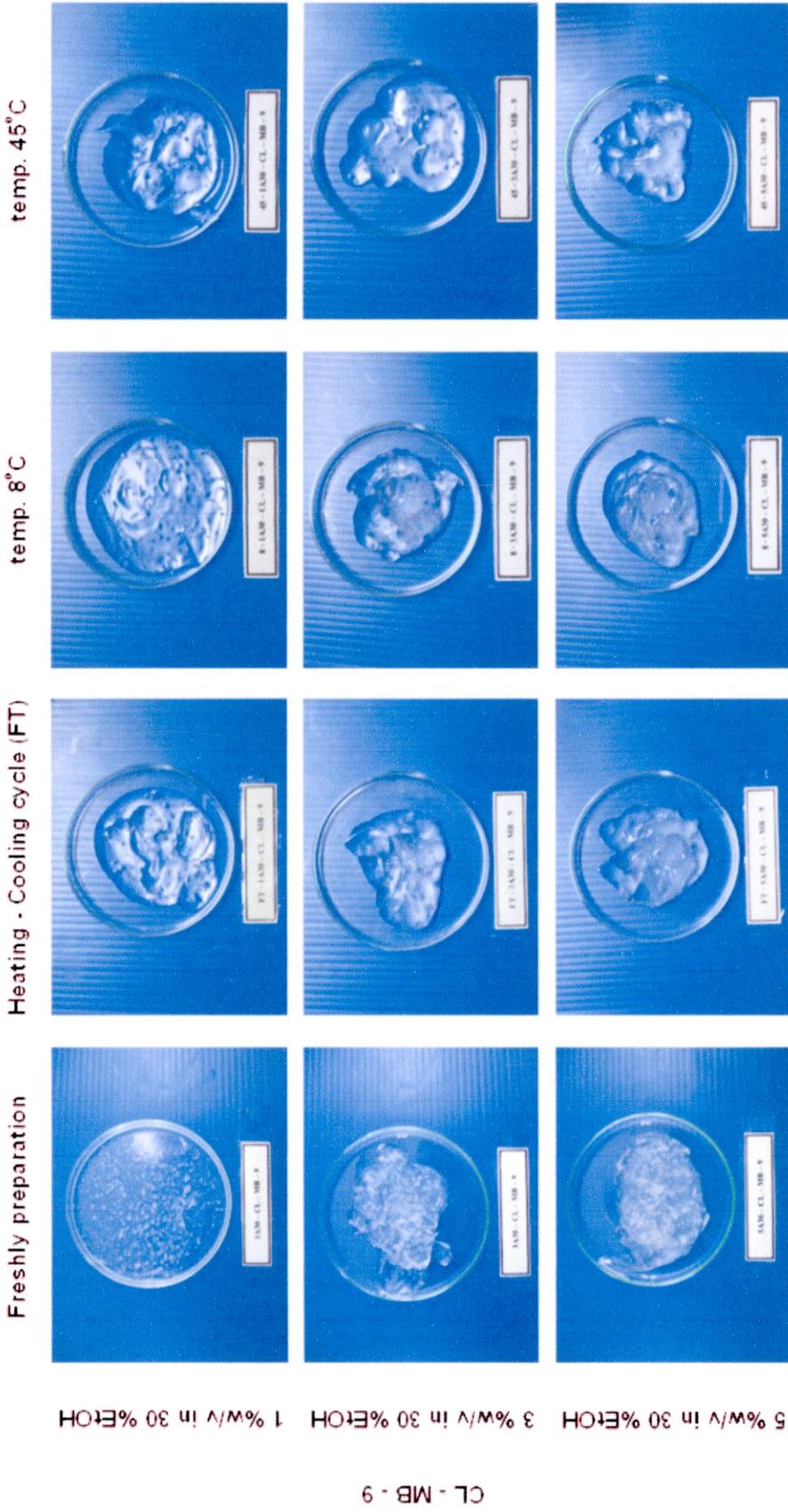


Figure 3.14F Stability of cross-linked carboxymethyl modified mungbean starch with DCA 7% (CL-MB-7) gel in 30 %EtOH



CL - MB - 8

Figure 3.14G Stability of cross-linked carboxymethyl modified mungbean starch with DCA 8% (CL-MB-8) gel in 30 %EtOH



CL - MB - 9

Figure 3.14H Stability of cross-linked carboxymethyl modified mungbean starch with DCA 9% (CL-MB-9) gel in 30%EtOH

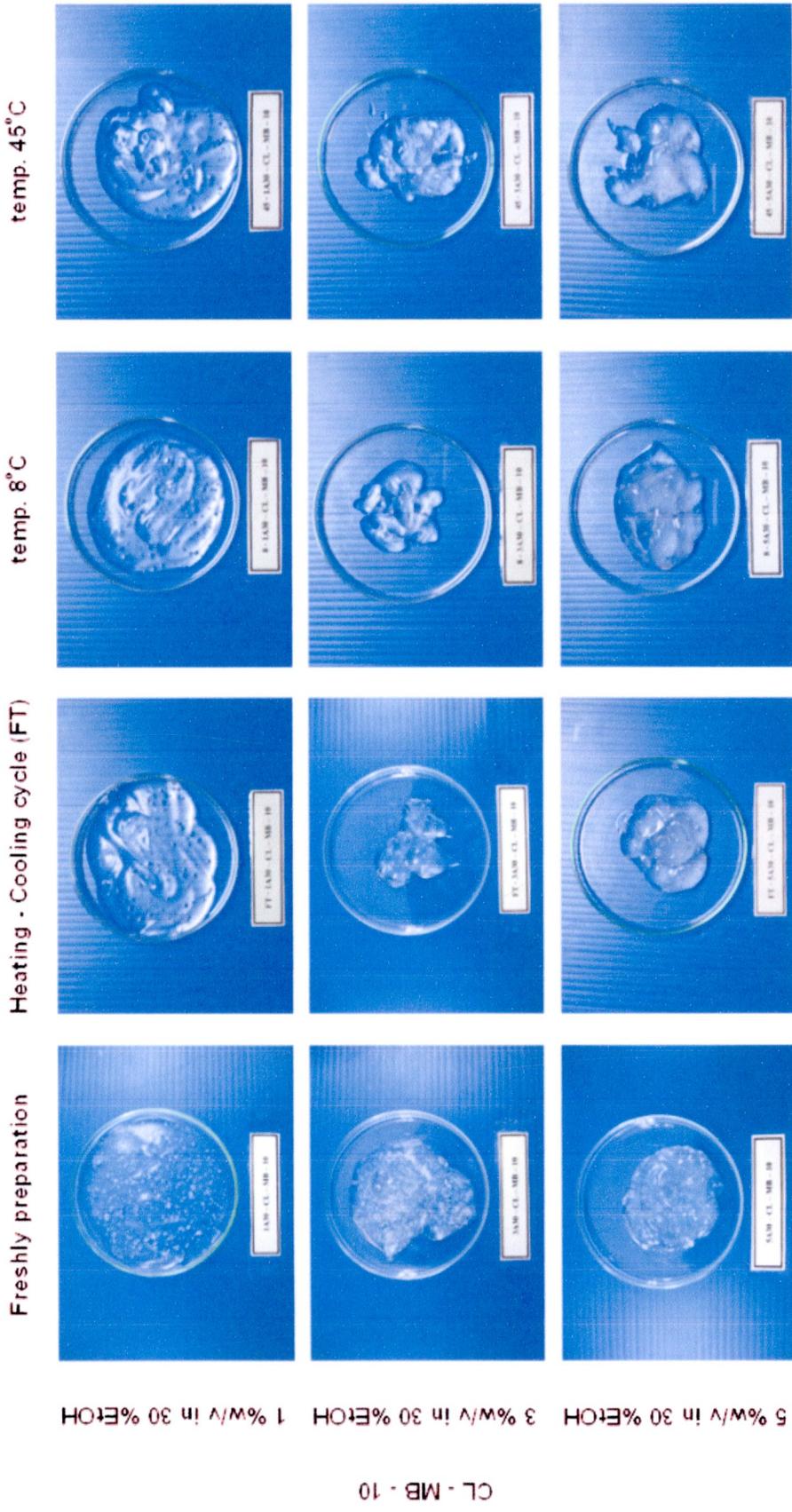


Figure 3.14I Stability of cross-linked carboxymethyl modified mungbean starch with DCA 10% (CL-MB-10) gel in 30 %EtOH

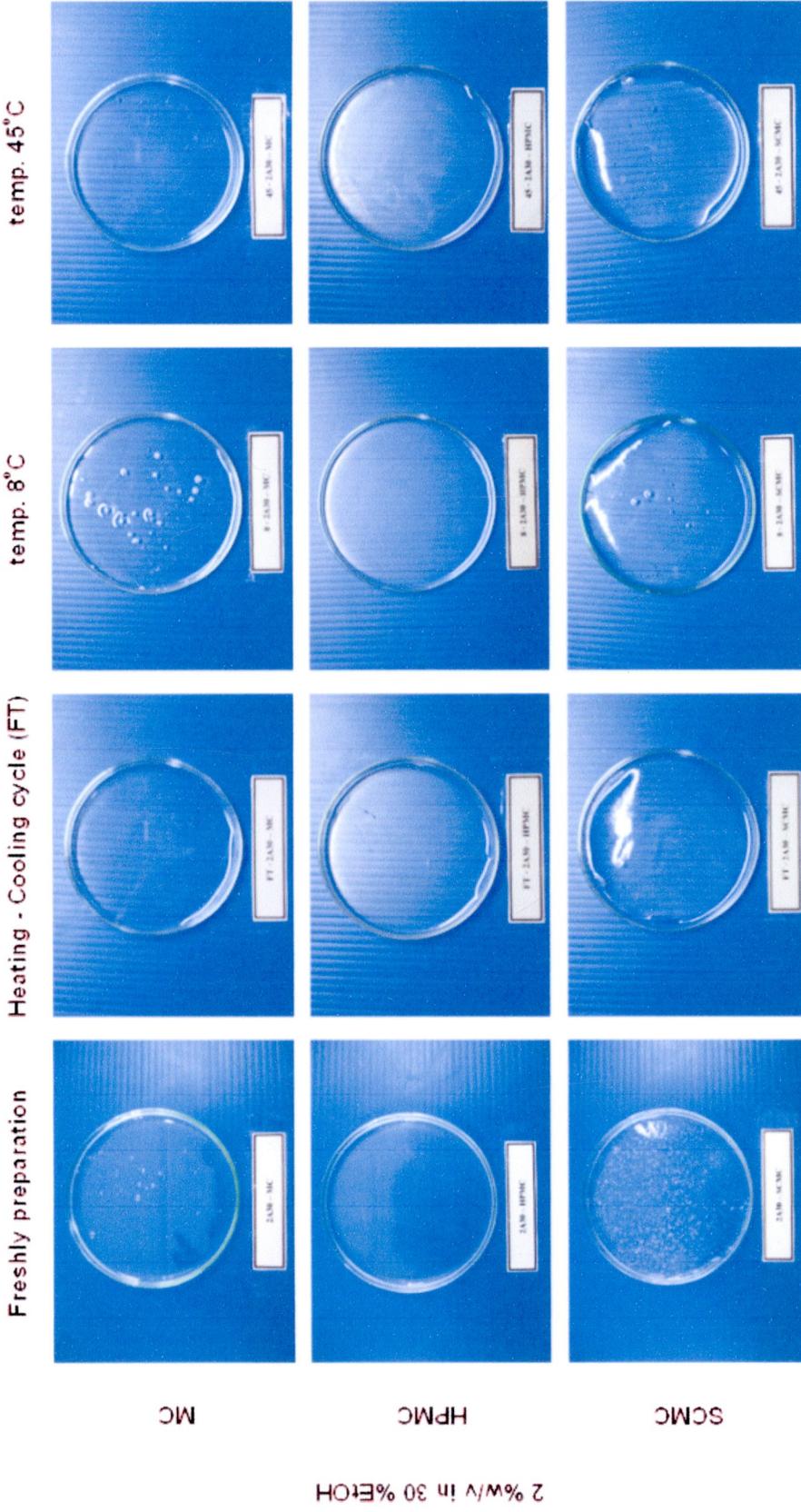


Figure 3.14J Stability of 3-commercial polymer gels (as HPMC, MC, SCMC) at 2%w/v in 30 %EtOH

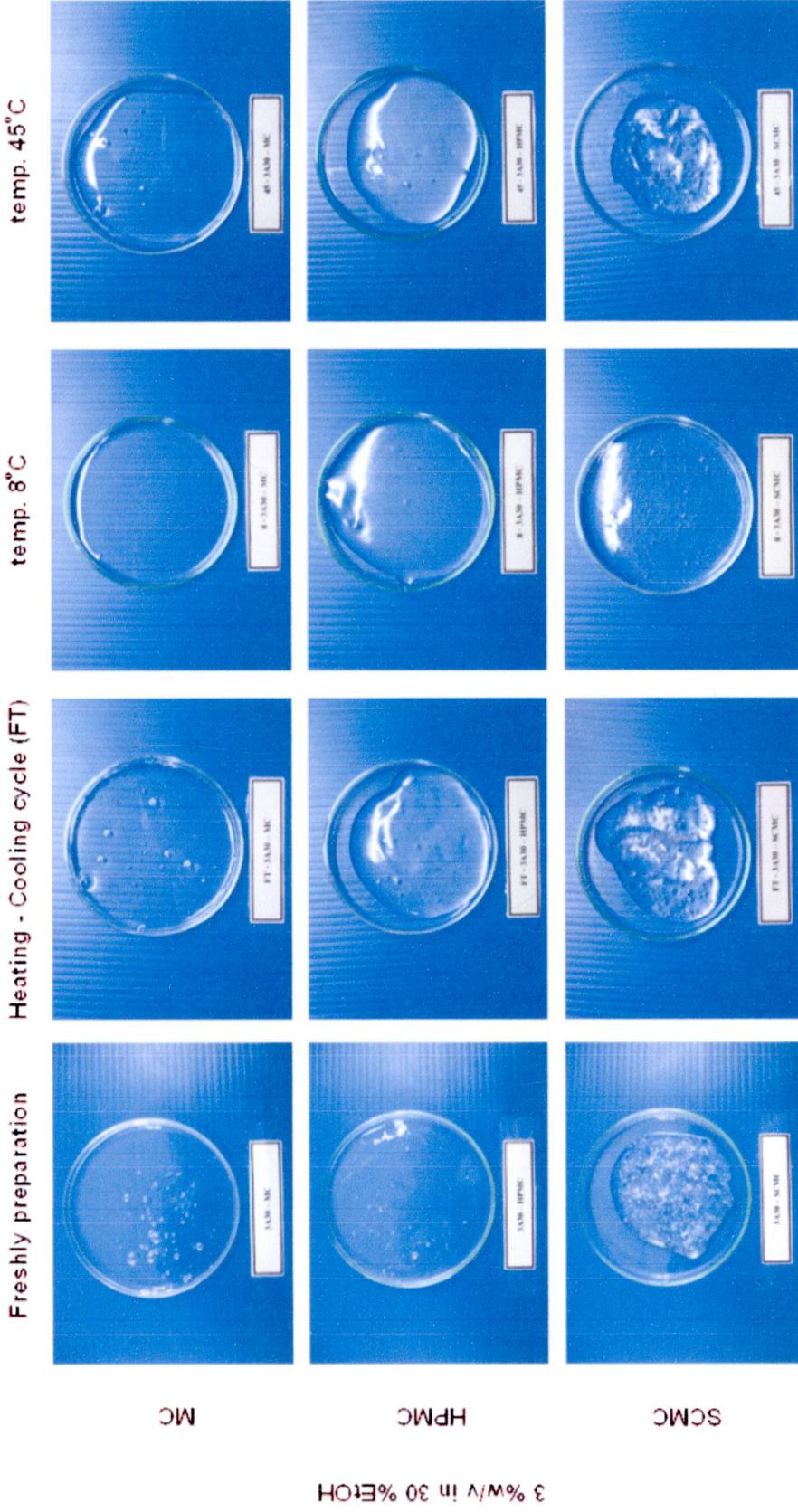


Figure 3.14K Stability of 3-commercial polymer gels (as HPMC, MC, SCMC) at 3%w/v in 30 %EtOH

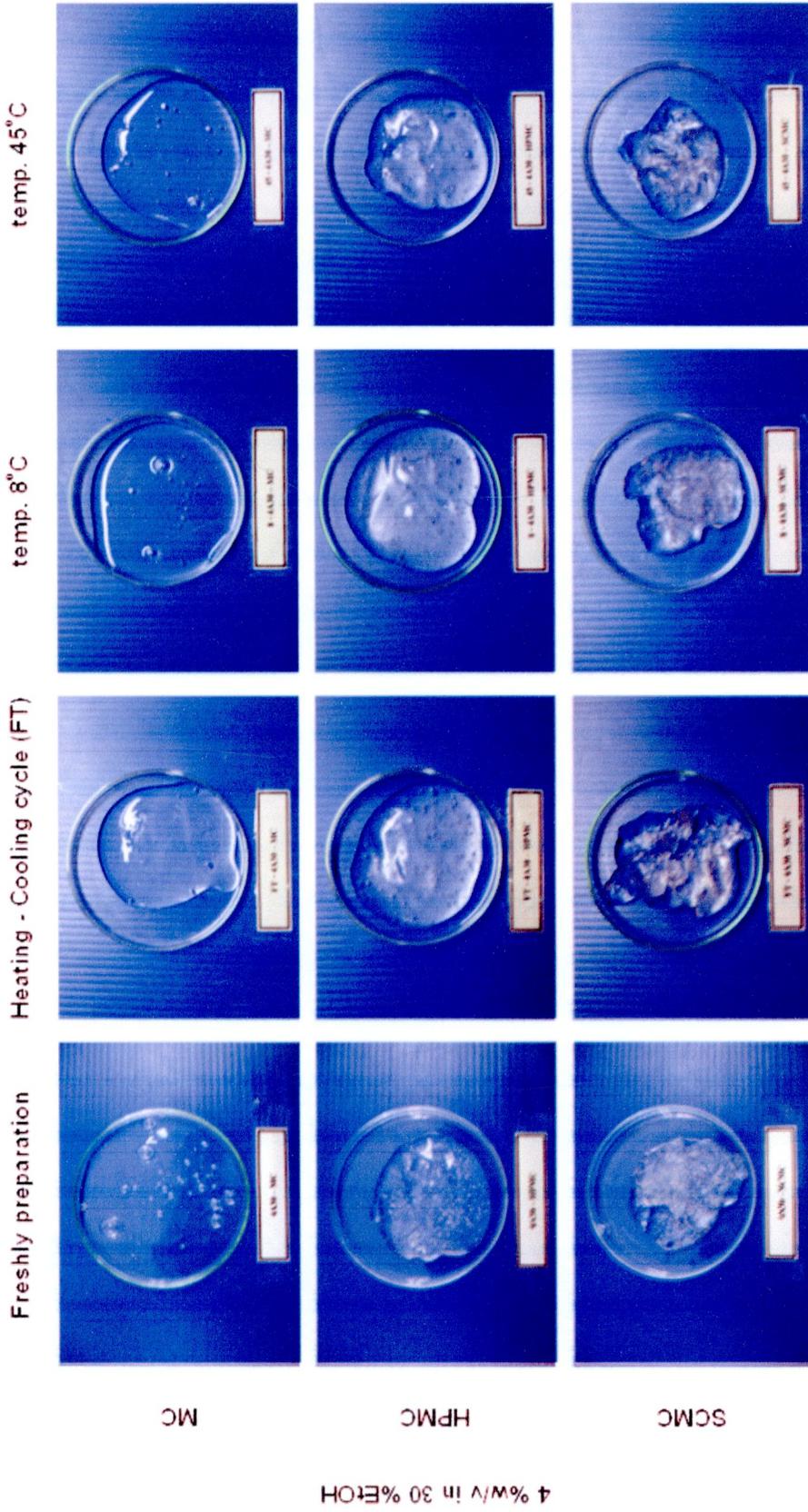


Figure 3.14L Stability of 3-commercial polymer gels (as HPMC, MC, SCMC) at 4%w/v in 30 %EtOH

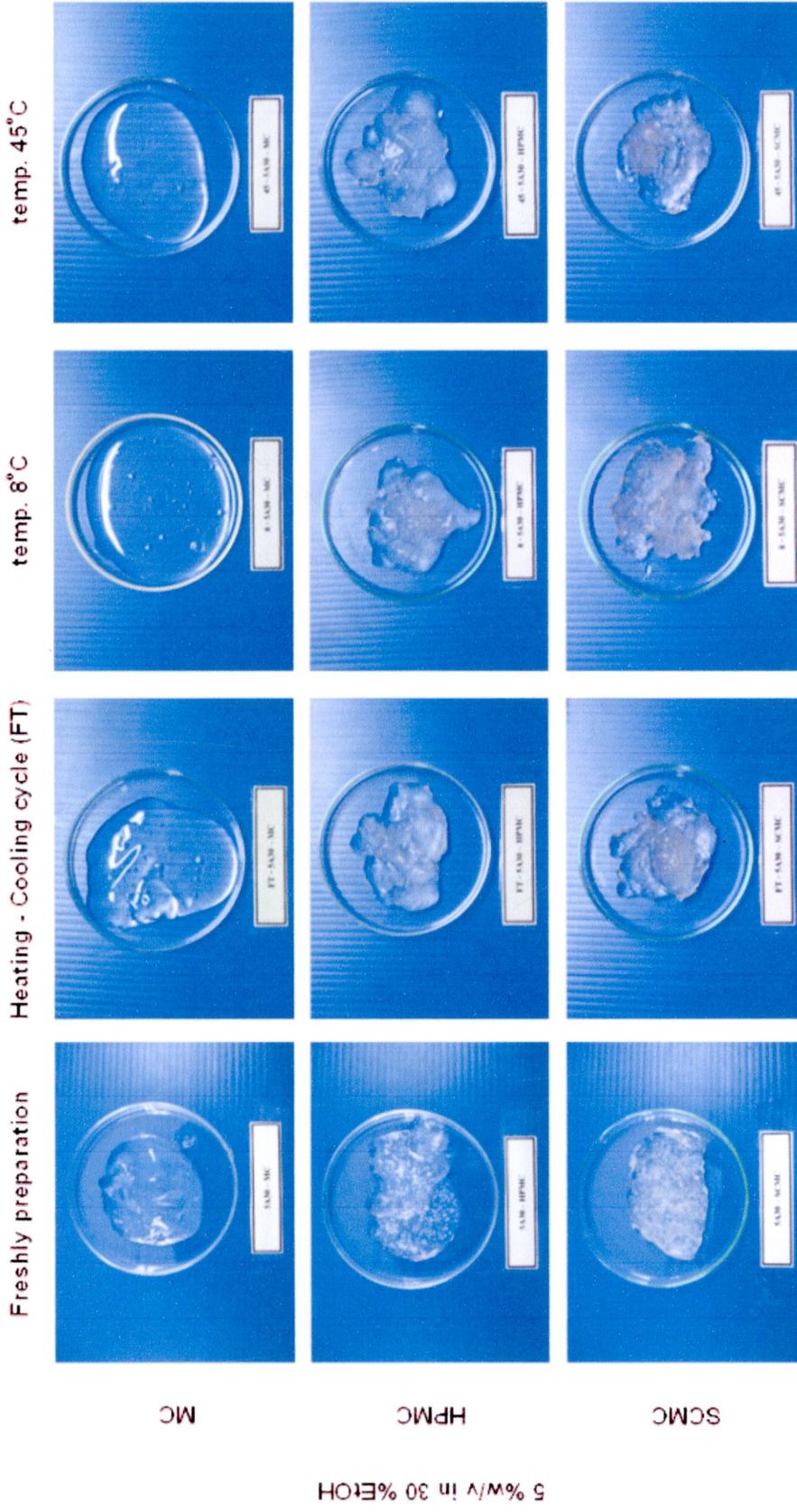
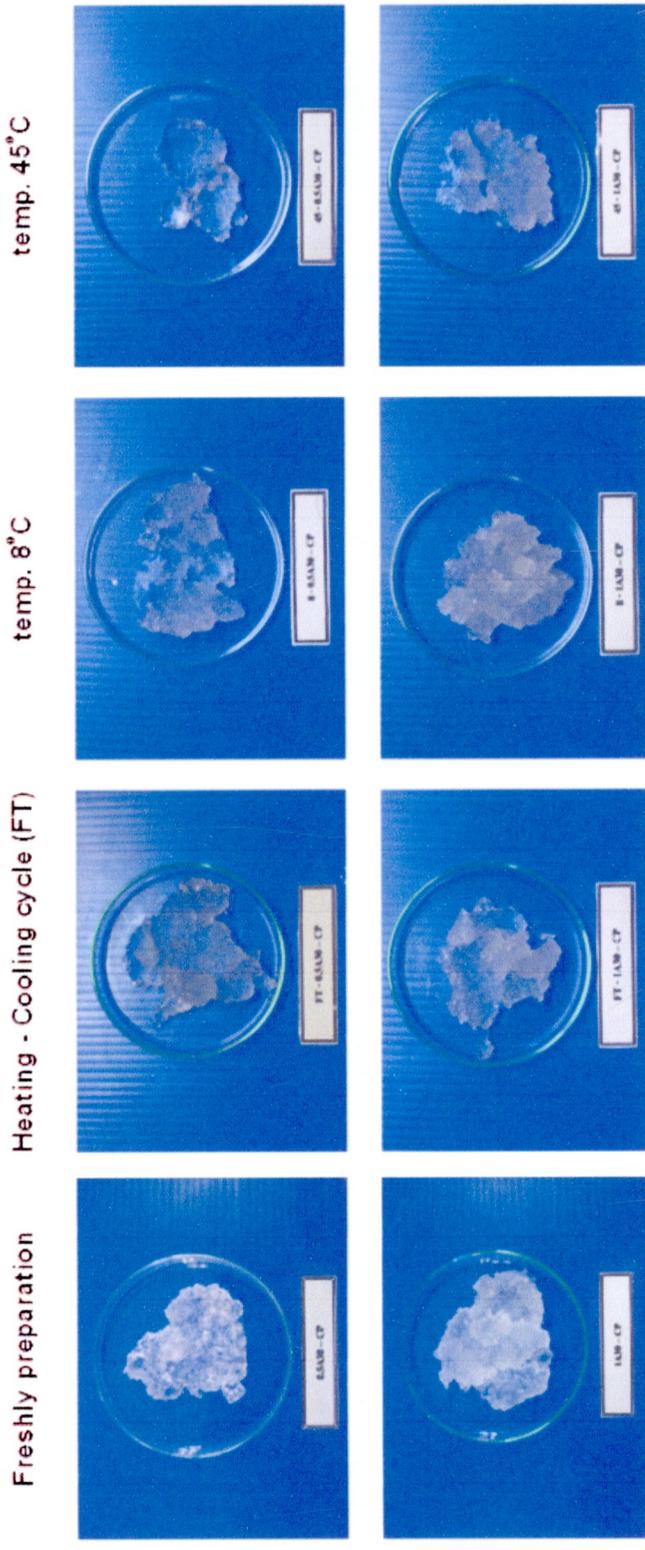


Figure 3.14M Stability of 3-commercial polymer gels (as HPMC, MC, SCMC) at 5%w/v in 30 %EtOH



0.5 %w/v in 30 %EtOH CP
 1 %w/v in 30 %EtOH

Figure 3.14N Stability of commercial polymer gel (Carbopol 940) at 0.5%w/v and 1.0%w/v in 30 %EtOH

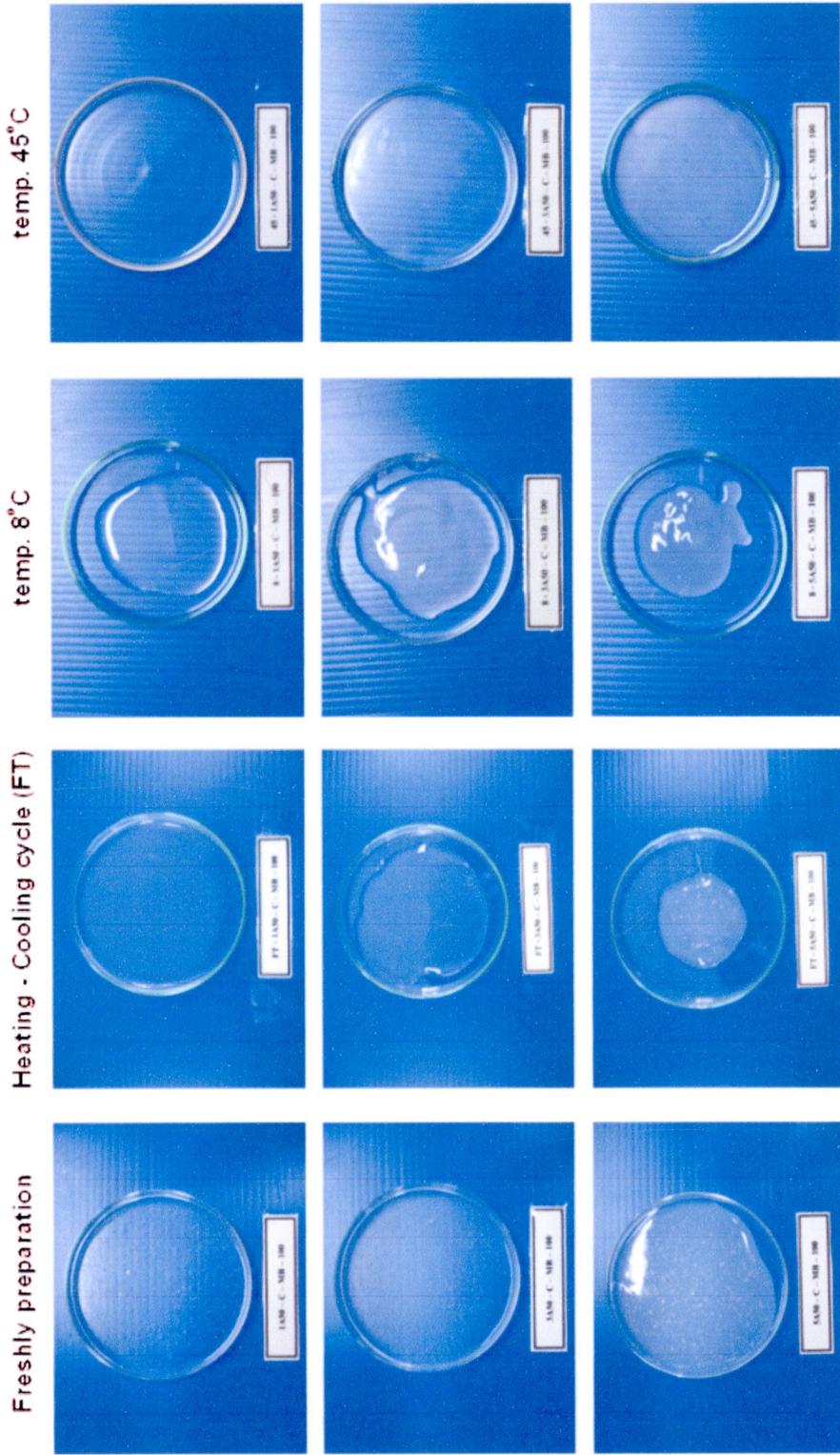


Figure 3.15A Stability of carboxymethyl modified mungbean starch (C-MB-100) gel in 50 %EtOH

5% w/v in 50 %EtOH 3% w/v in 50 %EtOH 1% w/v in 50 %EtOH

C - MB - 100

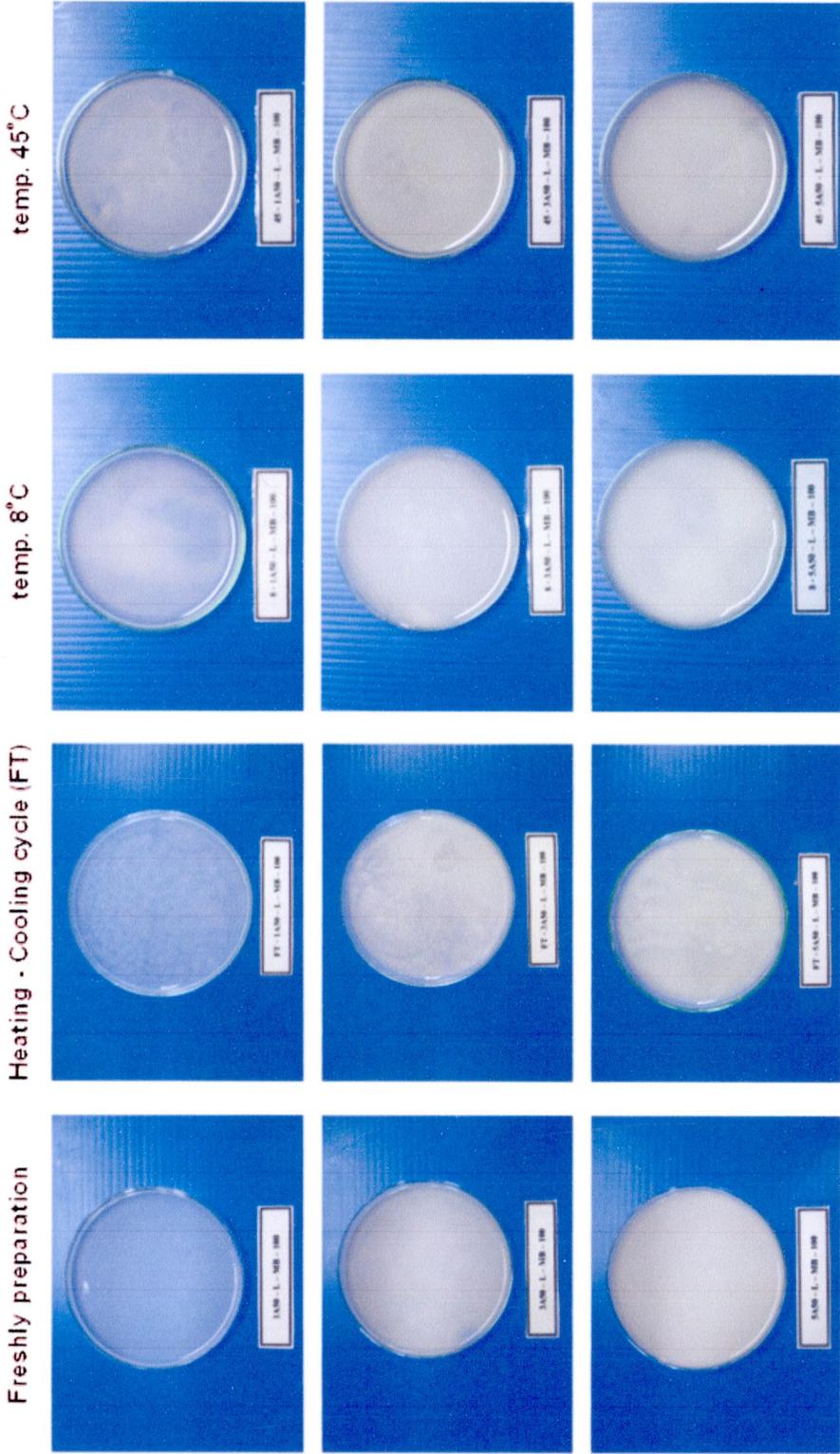


Figure 3.15B Stability of cross-linked modified mungbean starch (L-MB-100) suspension in 50 %EtOH

L - MB - 100

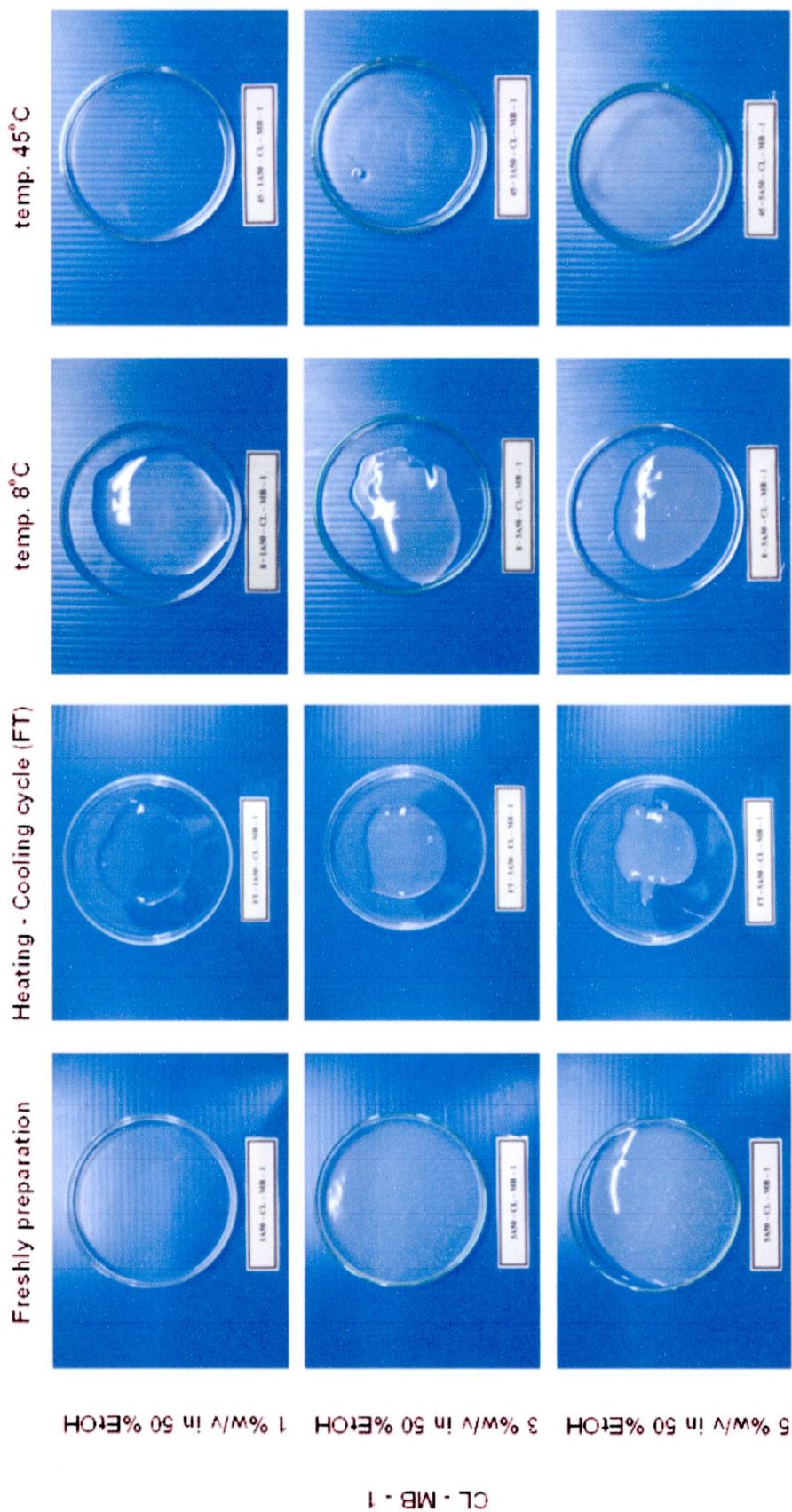
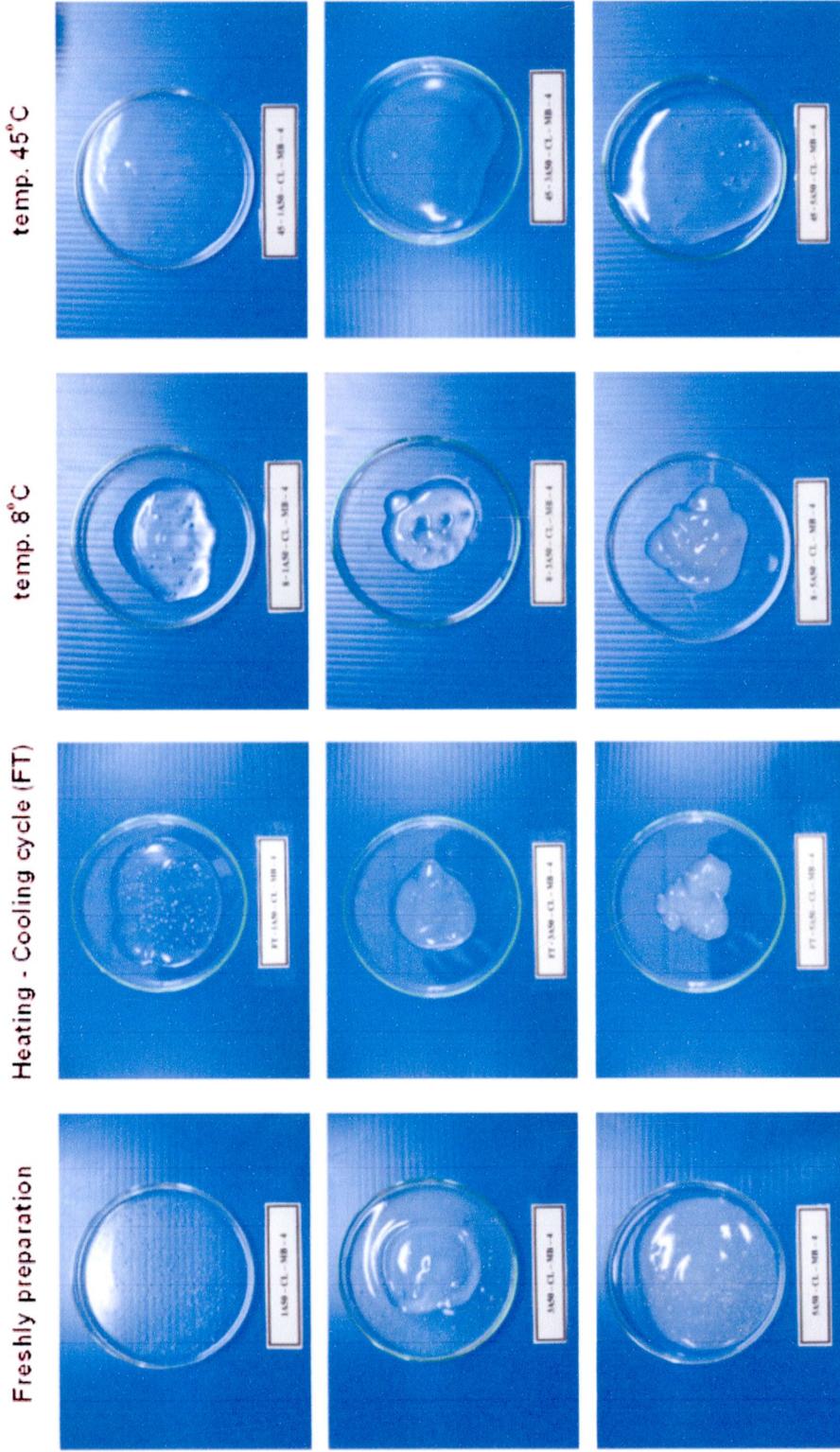


Figure 3.15C Stability of cross-linked carboxymethyl modified mungbean starch with DCA 1% (CL-MB-1) gel in 50 %EtOH



5 %w/v in 50 %EtOH 3 %w/v in 50 %EtOH 1 %w/v in 50 %EtOH

CL - MB - 4



Figure 3.15D Stability of cross-linked carboxymethyl modified mungbean starch with DCA 4% (CL-MB-4) gel in 50 %EtOH

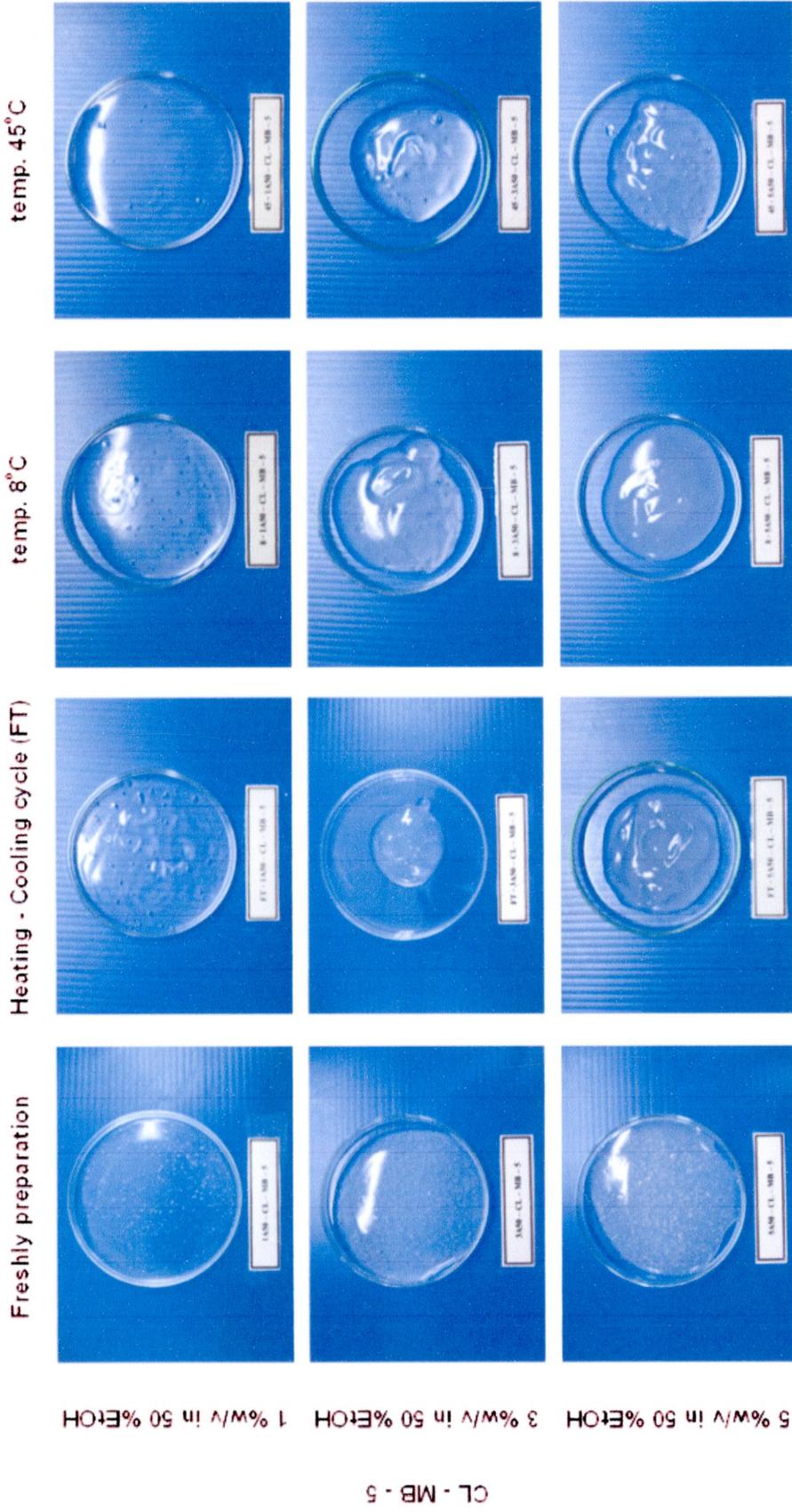


Figure 3.15E Stability of cross-linked carboxymethyl modified mungbean starch with DCA 5% (CL-MB-5) gel in 50 %EtOH

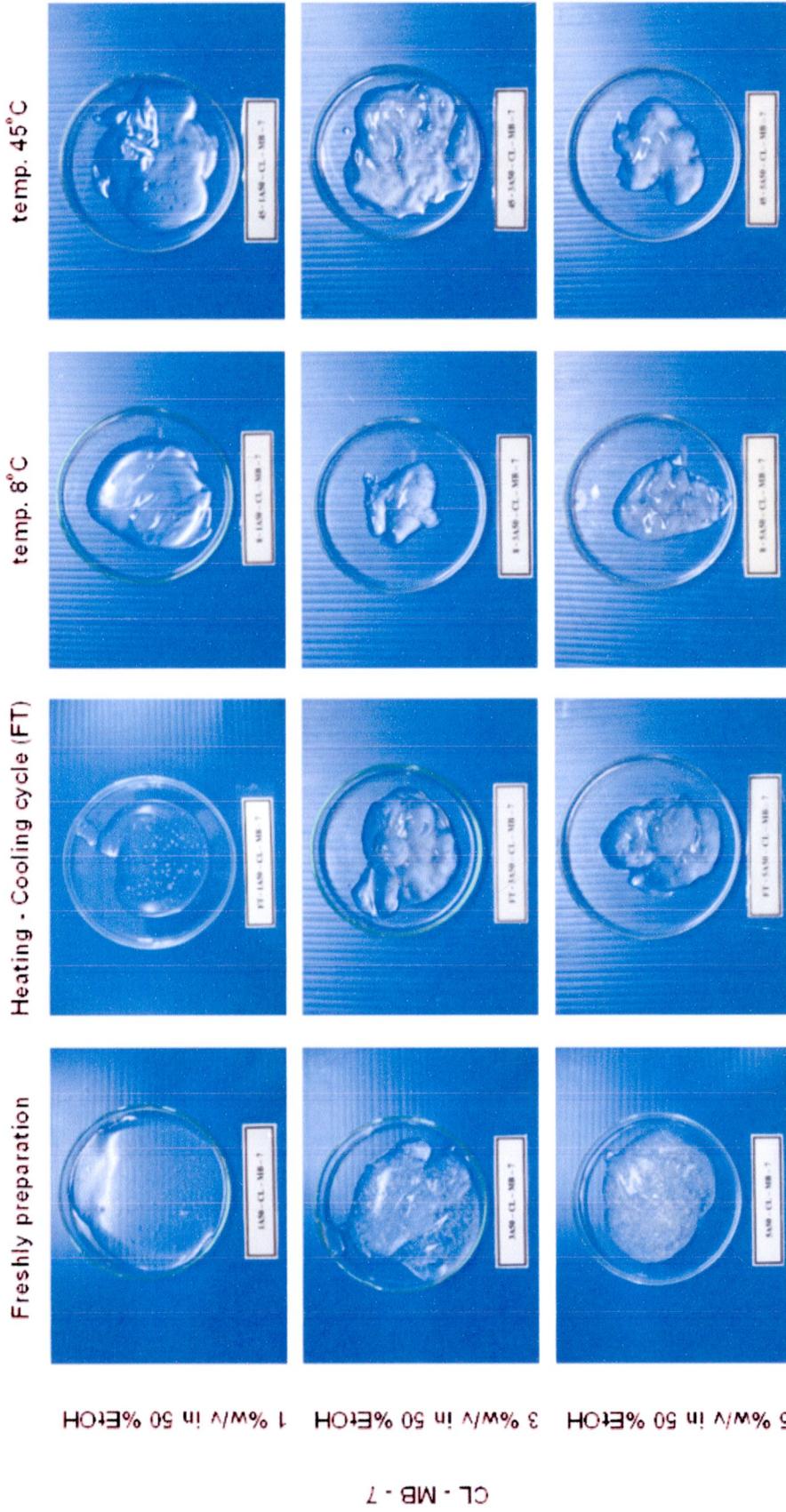


Figure 3.15F Stability of cross-linked carboxymethyl modified mungbean starch with DCA 7% (CL-MB-7) gel in 50 %EtOH

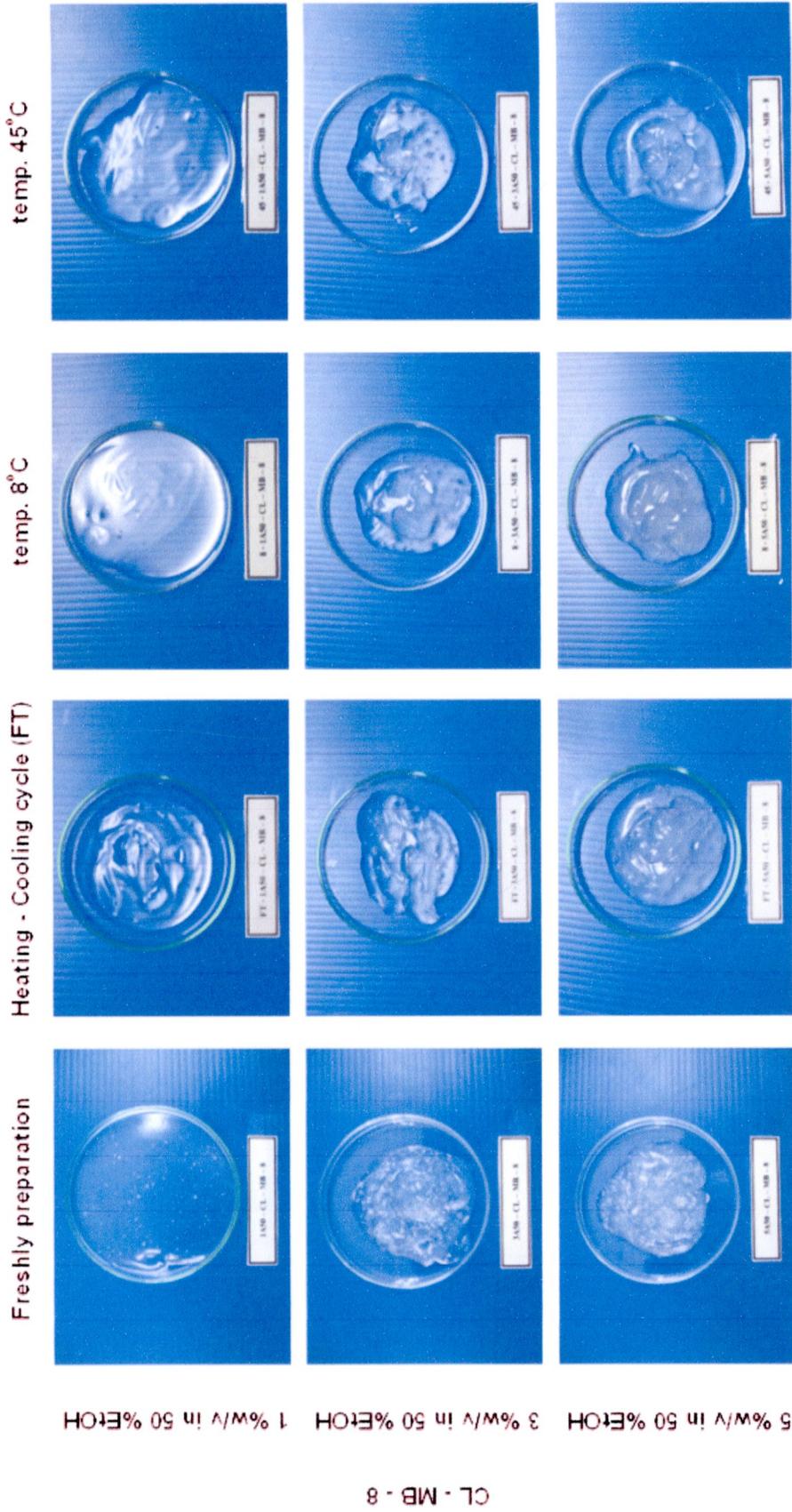


Figure 3.15G Stability of cross-linked carboxymethyl modified mungbean starch with DCA 8% (CL-MB-8) gel in 50 %EtOH

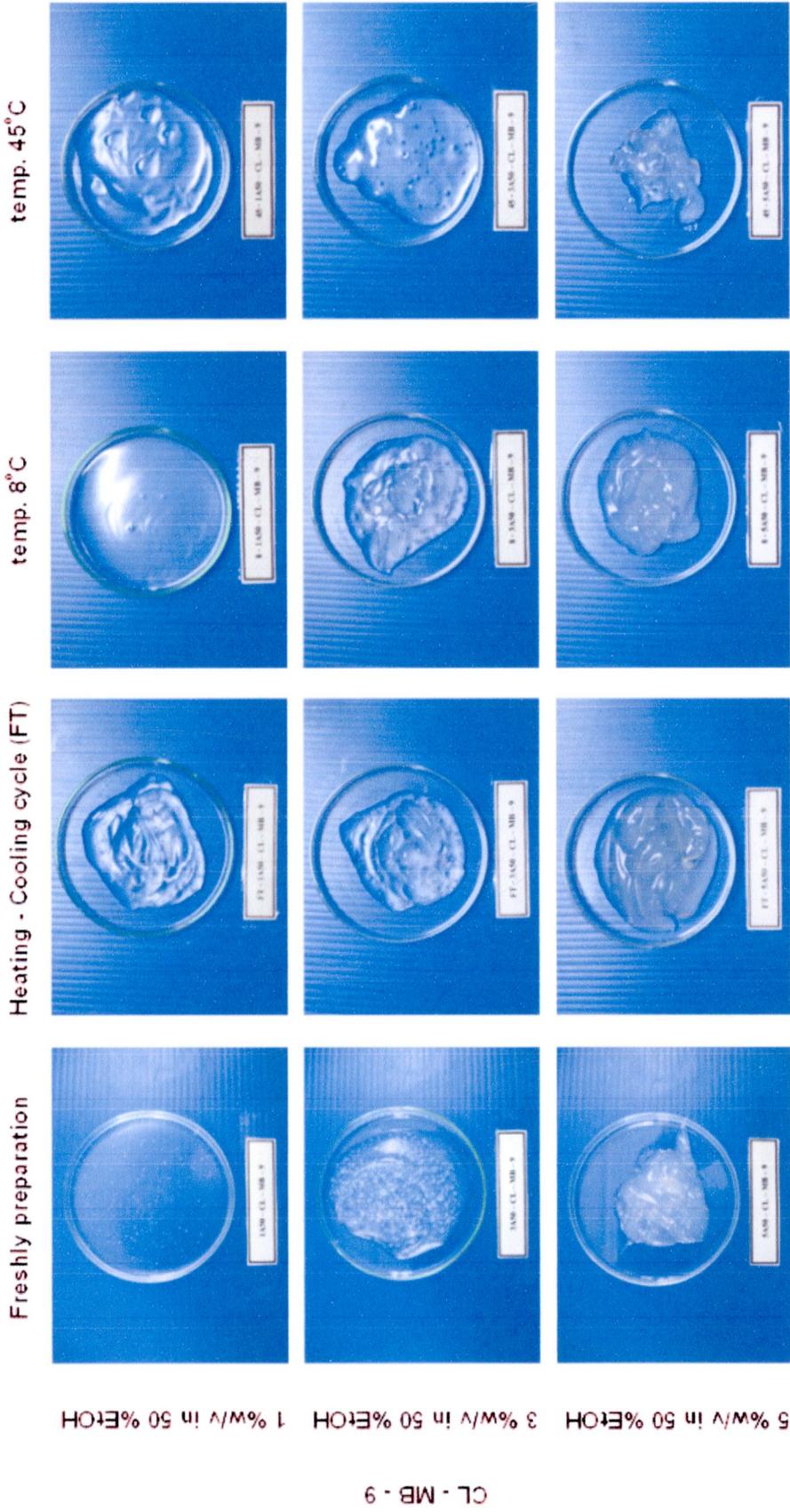


Figure 3.15H Stability of cross-linked carboxymethyl modified mungbean starch with DCA 9% (CL-MB-9) gel in 50 %EtOH

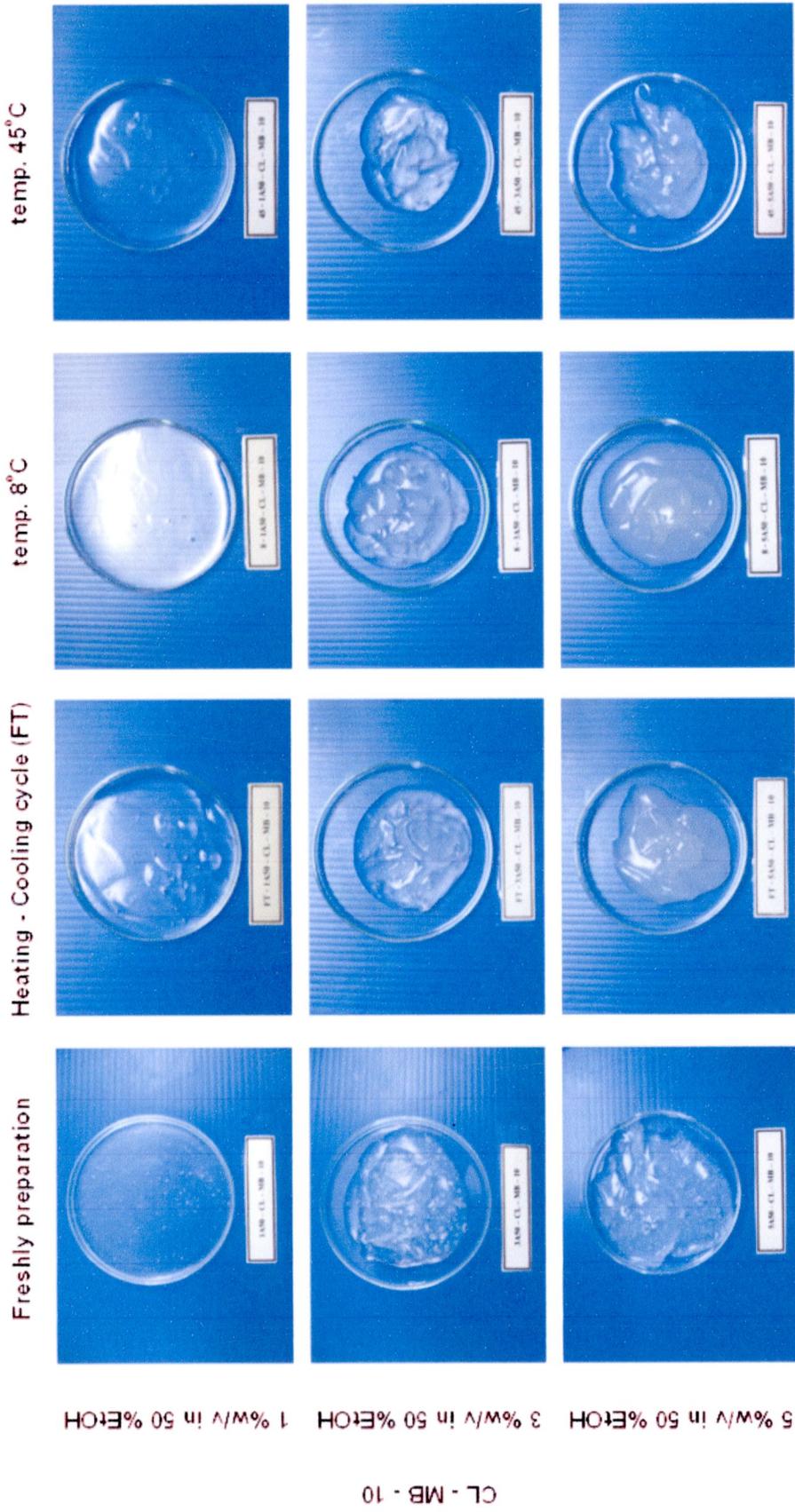


Figure 3.15I Stability of cross-linked carboxymethyl modified mungbean starch with DCA 10% (CL-MB-10) gel in 50 %EtOH

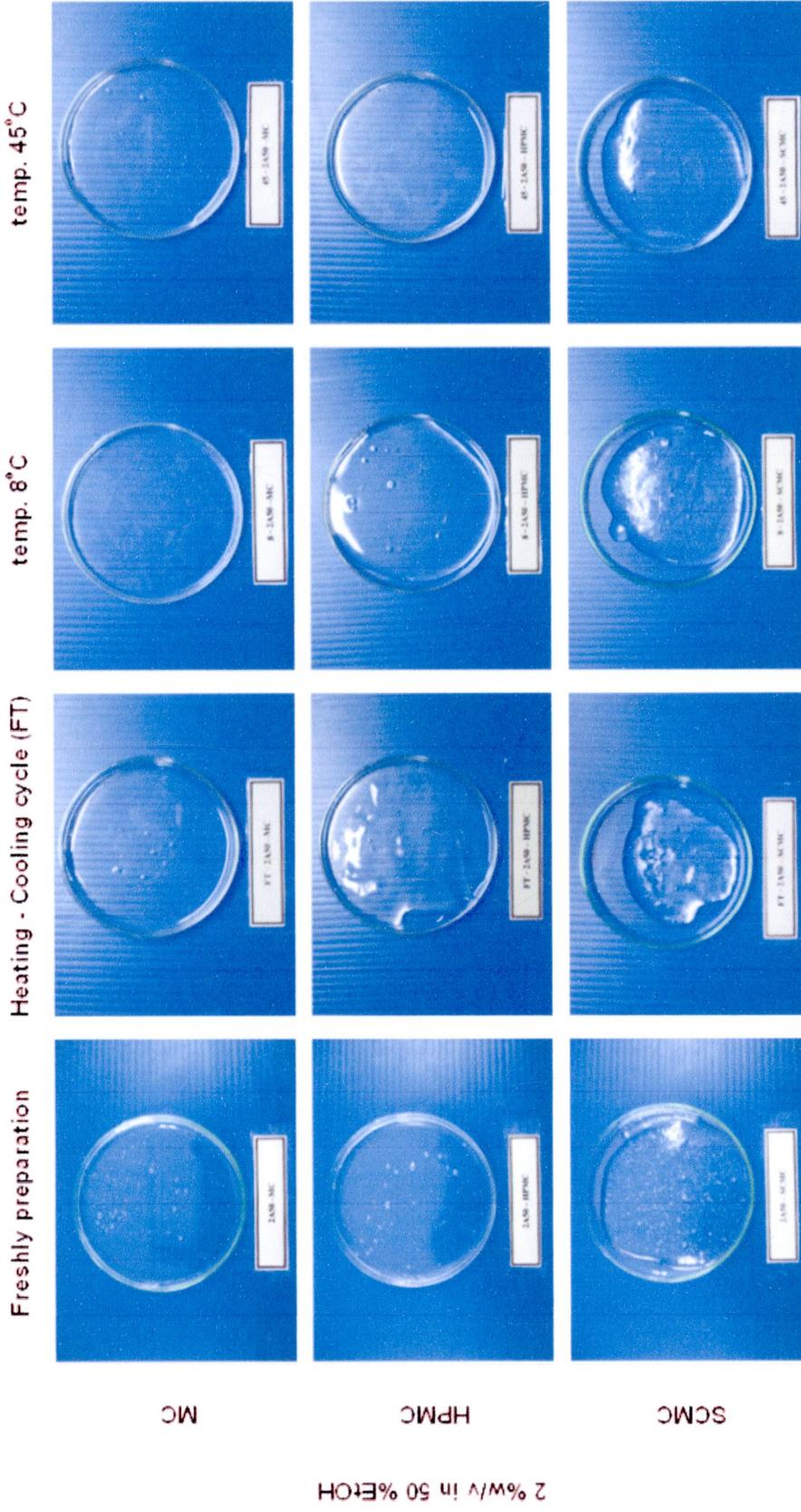
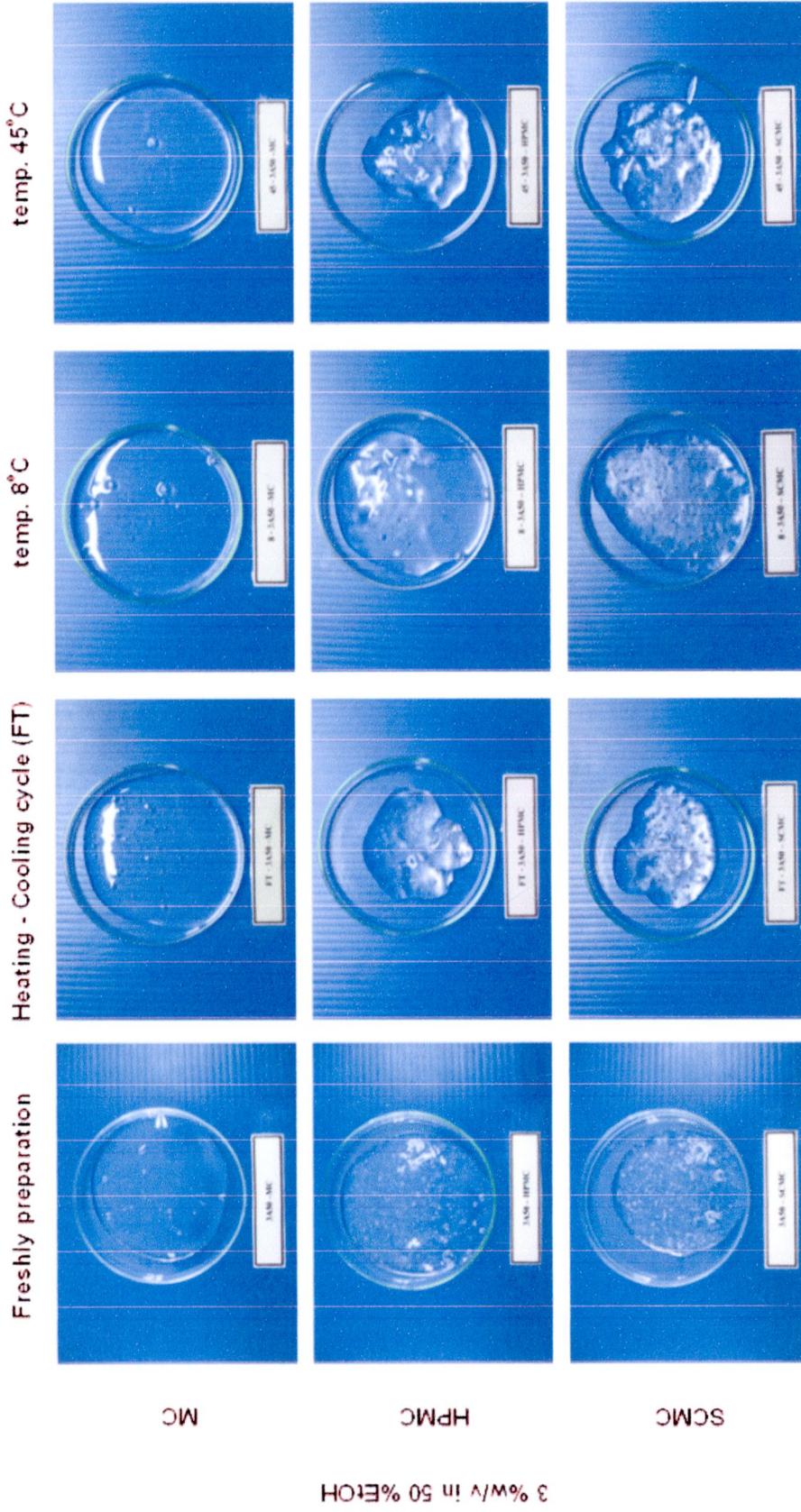


Figure 3.15J Stability of 3-commercial polymer gels (as HPMC, MC, SCMC) at 2%w/v in 50 %EtOH



3 %w/v in 50 %EtOH

Figure 3.15K Stability of 3-commercial polymer gels (as HPMC, MC, SCMC) at 3%w/v in 50 %EtOH

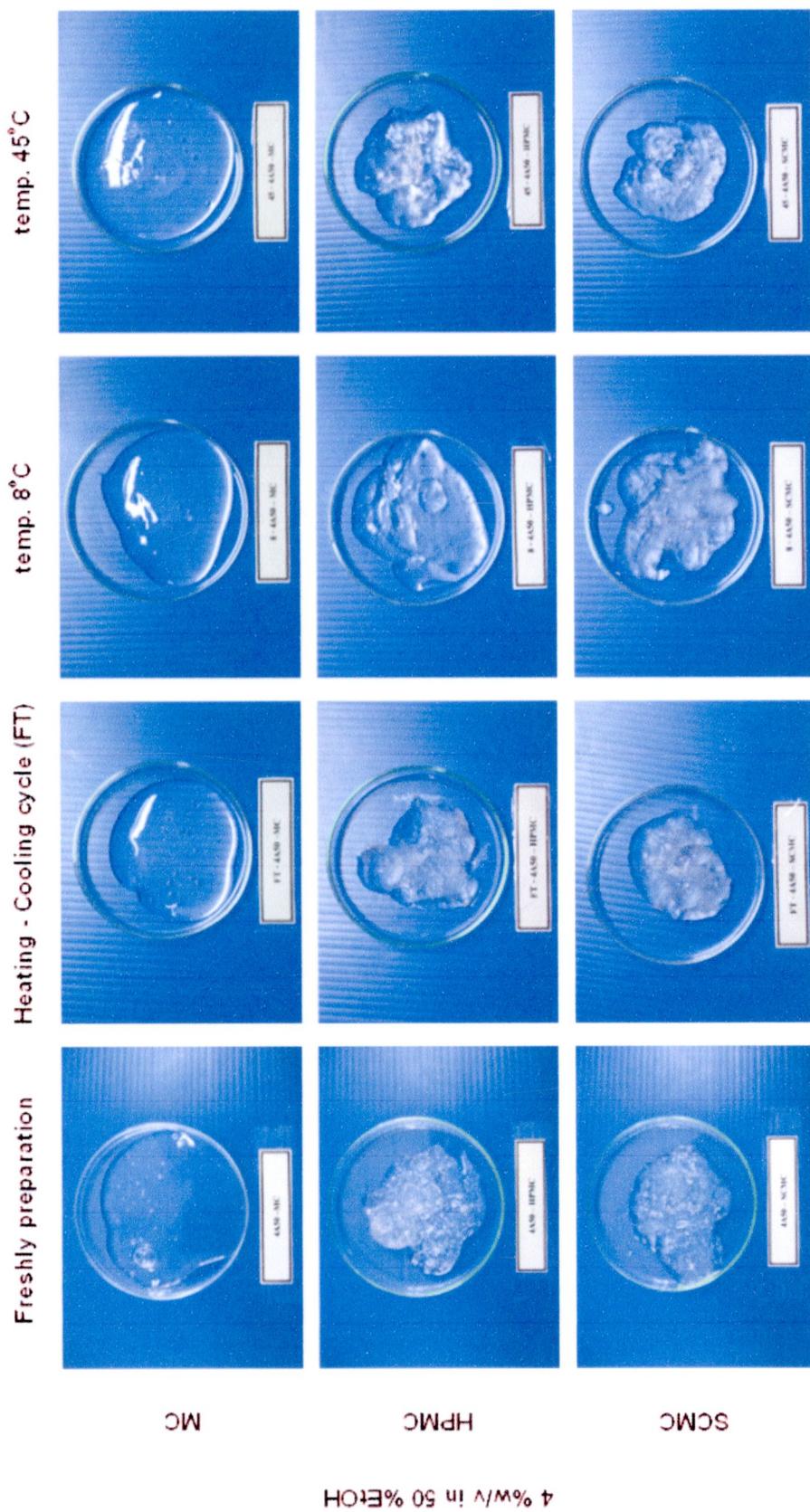


Figure 3.15L Stability of 3-commercial polymer gels (as HPMC, MC, SCMC) at 4%w/v in 50 %EtOH

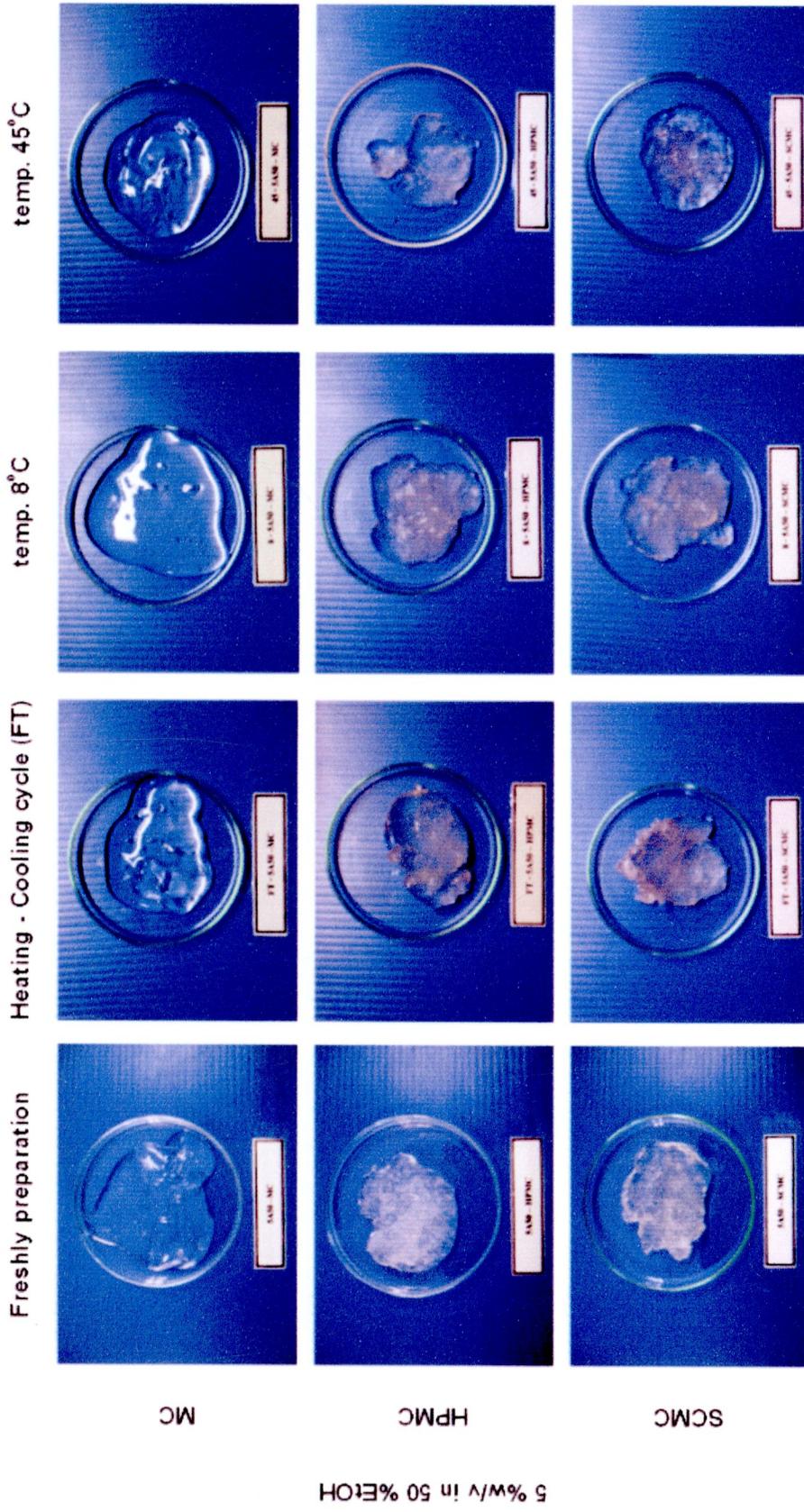


Figure 3.15M Stability of 3-commercial polymer gels (as HPMC, MC, SCMC) at 5%w/v in 50 %EtOH

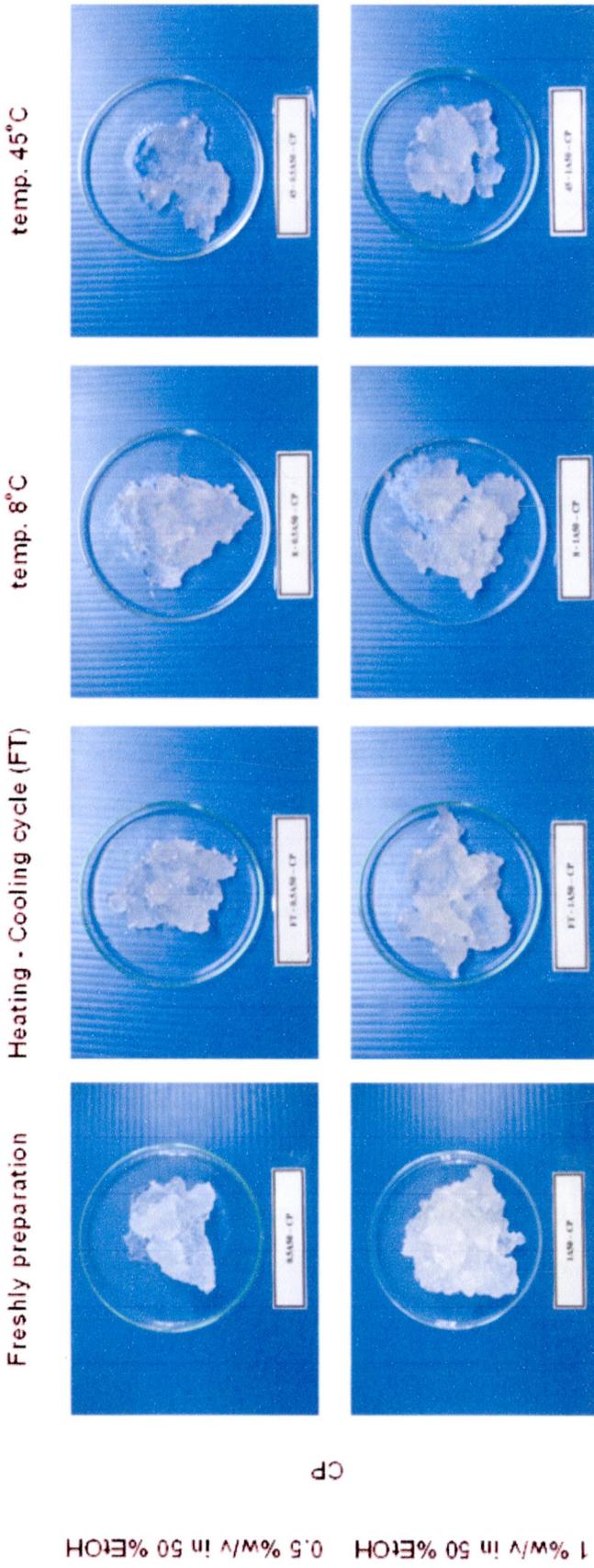


Figure 3.15N Stability of commercial polymer gel (Carbopol 940) at 0.5%w/v and 1.0%w/v in 50 %EtOH

3.5.2 Viscosity, pH and clarity of cross-linked carboxymethyl modified mungbean starch gels in the alcohol solution

The study of alcohol tolerability was studied the changing of physico-chemical properties, included pH, clarity and viscosity of 7-CL-MBs. The modified starch powder was dissolved in 3 media: EtOH:H₂O mix of ratio 0:100, 30:70 and 50:50, at 1, 3 and 5%w/v. The experiments was determined against CMMS, cross-linked MB and four commercial polymers as CP, HPMC, MC and SCMC. The gels was stored at 8°C and 45°C for 3 month, and underwent a HC stability (8 cycles—each cycle consisted of 2 days at 8°C and another 2 days at 45°C). The facts were compared with the data before stability test (freshly preparation), shown in Table 3.8A-3.8E (viscosity), Table 3.9A-3.9E (Clarity) and Table 3.10A-3.10E (pH).

The sample of rheograms of CL-MBs in the EtOH:H₂O mix of ratio 0:100, 30:70 and 50:50, presented in Figure 3.16, show a pseudoplastic flow with thixotropy; very important behavior when using as a gelling agent. The rheological profile of CL-MBs showed an increase in solution viscosity compared to that of CMMS. The viscosities of 3%w/v solution in EtOH:H₂O mix of ratio 0:100, 30:70 and 50:50, ranged between 2.51-6.96, 2.66-6.86 and 2.36-5.10 Pa.s., respectively (Table 3.7A-3.7E). Under accelerated conditions, the characteristics of CL-MB gel were not different from those of CMMS gel. The viscosity of CL-MB solutions after being subjected to HC cycles remained 2 times higher than that of CMMS at the same concentration. The viscosity of CL-MB-7, CL-MB-8, CL-MB-9 and CL-MB-10 in EtOH:H₂O mix of ratio 30:70 at 1, 3 and 5%w/v, was unchanged or only slightly changed when compared to the water solution. The viscosity of CL-MBs gel was significantly less than for the four commercial polymers, but had a gel like appearance. The CL-MB gels that exhibited good viscosity were CL-MB-7 and CL-MB-8, because they hade slightly changed values after the stability test at 8°C and 45°C, after the HC cycle stability test (not significant). Therefore, CL-MB-7, CL-MB-8, CL-MB-9 and CL-MB-10 can resist up to 30%v/v EtOH and exhibited greater tolerance at high concentration.

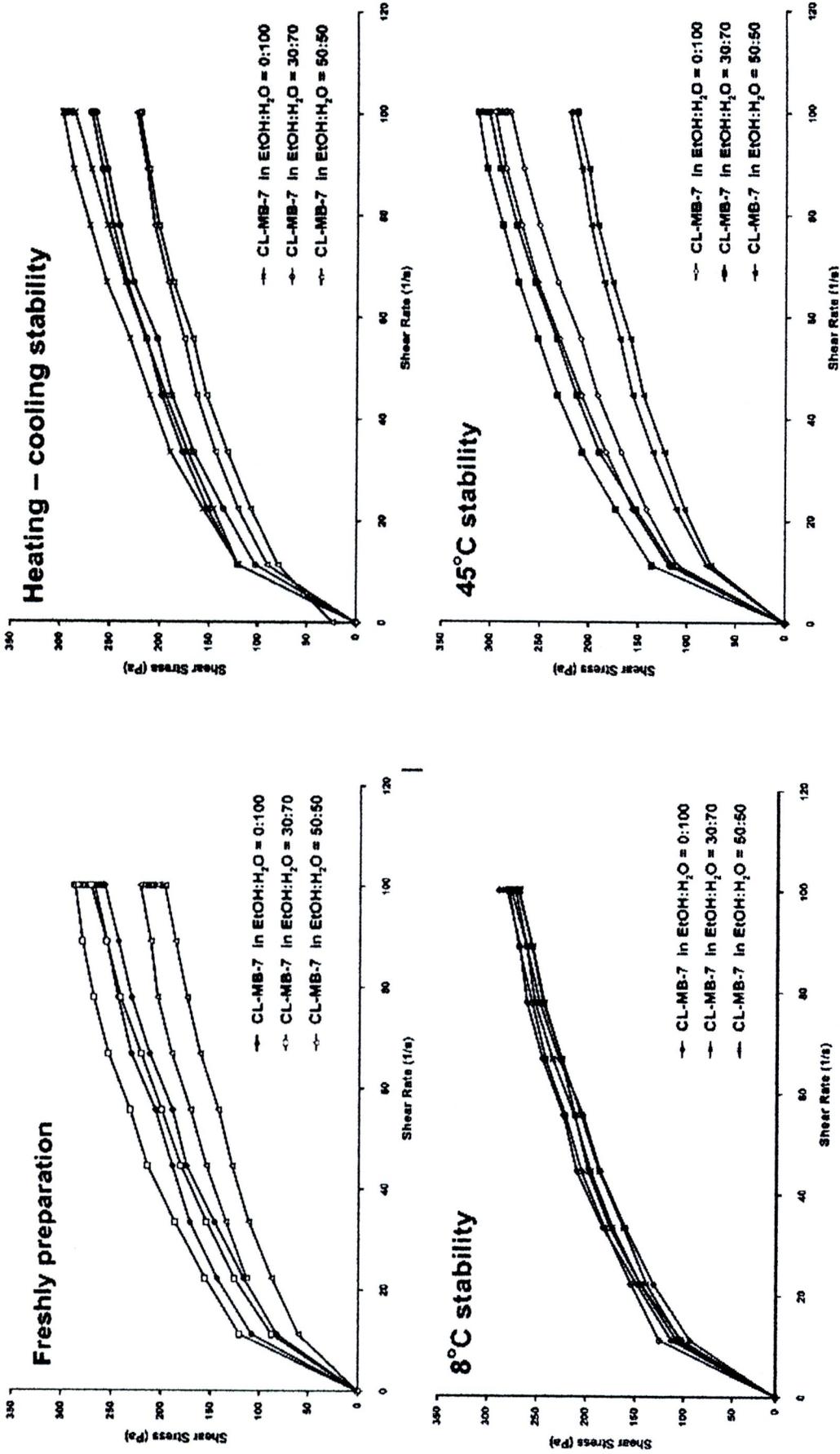


Figure 3.16 The sample of rheograms of CL-MB-7 at 1%w/v conc. in the alcohol solution, stored in 8°C, 45°C and HC cycle stability

Table 3.8 Viscosity of CL-MBs with varied conditions compared with CMMS, cross-linked MB and 4-commercial polymers in the alcohol solution

Conc. (% w/v)		Viscosity (Pa.s)											
		EtOH:H ₂ O (0:100)				EtOH:H ₂ O (30:70)				EtOH:H ₂ O (50:50)			
		Freshly prep.	FT cycle	8°C	45°C	Freshly prep.	FT cycle	8°C	45°C	Freshly prep.	FT cycle	8°C	45°C
C-MB-100													
1	1.768±0.02	0.291±0.01	N/A	N/A	1.346±0.01	0.869±0.01	1.232±0.02	0.762±0.01	1.293±0.01	0.717±0.01	0.845±0.02	0.748±0.01	
3	3.055±0.02	0.243±0.01	N/A	N/A	3.427±0.02	2.357±0.00	2.392±0.01	1.864±0.03	2.353±0.02	1.835±0.03	1.222±0.01	1.222±0.01	
5	6.554±0.11	1.599±0.02	N/A	N/A	5.512±0.05	4.616±0.07	3.828±0.05	2.597±0.03	4.135±0.01	4.448±0.03	2.240±0.08	2.255±0.04	
L-MB-100													
1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
3	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
CL-MB-1													
1	1.222±0.02	N/A	N/A	N/A	1.127±0.01	1.154±0.02	1.060±0.02	0.661±0.01	0.948±0.01	1.167±0.01	0.875±0.01	0.827±0.01	
3	2.510±0.05	N/A	N/A	N/A	2.660±0.01	2.567±0.04	2.614±0.02	2.863±0.02	2.363±0.01	2.139±0.04	1.868±0.02	0.968±0.02	
5	3.128±0.16	0.358±0.01	N/A	N/A	4.354±0.01	4.476±0.07	3.845±0.04	1.067±0.02	3.402±0.07	3.704±0.14	2.477±0.06	2.451±0.05	

Table 3.8 (cont.) Viscosity of CL-MBs with varied conditions compared with CMMS, cross-linked MB and 4-commercial polymers in the alcohol solution

Conc. (% w/v)		Viscosity (Pa.s)											
		EtOH:H ₂ O (0:100)				EtOH:H ₂ O (30:70)				EtOH:H ₂ O (50:50)			
		Freshly prep.	FT cycle	8°C	45°C	Freshly prep.	FT cycle	8°C	45°C	Freshly prep.	FT cycle	8°C	45°C
CL-MB-4													
1		1.700±0.02	0.797±0.01	0.461±0.01	N/A	1.738±0.02	1.935±0.02	1.789±0.03	1.559±0.01	1.461±0.02	1.476±0.02	1.543±0.01	1.623±0.01
3		3.589±0.07	1.465±0.03	0.920±0.01	1.377±0.02	3.780±0.04	4.802±0.05	3.862±0.02	3.894±0.02	3.387±0.02	3.817±0.02	3.862±0.02	2.809±0.03
5		5.225±0.03	3.216±0.03	0.211±0.01	N/A	5.985±0.09	6.392±0.09	6.205±0.07	6.080±0.10	4.763±0.07	4.717±0.01	4.262±0.05	4.225±0.06
CL-MB-5													
1		1.862±0.02	1.183±0.02	0.881±0.01	0.529±0.01	1.860±0.02	2.186±0.04	1.899±0.02	1.899±0.04	1.488±0.03	1.575±0.03	1.965±0.03	1.865±0.03
3		4.476±0.08	1.741±0.01	1.667±0.03	1.522±0.02	4.681±0.02	4.898±0.06	4.382±0.06	4.850±0.04	3.528±0.02	4.002±0.07	4.382±0.06	3.817±0.04
5		6.280±0.05	3.493±0.01	6.228±0.02	4.531±0.07	7.191±0.10	6.982±0.05	7.578±0.10	6.980±0.13	5.076±0.02	5.709±0.08	5.807±0.01	5.835±0.03
CL-MB-7													
1		2.385±0.01	2.956±0.01	2.946±0.01	2.947±0.05	2.243±0.02	2.654±0.02	2.269±0.03	4.640±0.07	1.772±0.03	2.238±0.03	2.299±0.04	2.199±0.04
3		6.962±0.07	7.219±0.04	7.985±0.03	7.591±0.03	6.861±0.02	7.069±0.13	6.825±0.01	8.469±0.06	5.104±0.05	7.134±0.07	6.488±0.11	5.998±0.10
5		10.023±0.02	7.430±0.06	8.363±0.06	8.359±0.08	11.250±0.18	10.522±0.19	10.769±0.15	11.372±0.15	7.391±0.06	8.259±0.04	8.082±0.02	8.072±0.14

Table 3.8 (cont.) Viscosity of CL-MBs with varied conditions compared with CMMS, cross-linked MB and 4-commercial polymers in the alcohol solution

Conc. (% w/v)		Viscosity (Pa.s)											
		EtOH:H ₂ O (0:100)				EtOH:H ₂ O (30:70)				EtOH:H ₂ O (50:50)			
		Freshly prep.	FT cycle	8°C	45°C	Freshly prep.	FT cycle	8°C	45°C	Freshly prep.	FT cycle	8°C	45°C
CL-MB-8													
1	2.288±0.03	1.893±0.01	1.835±0.02	1.339±0.01	2.108±0.03	2.620±0.01	2.254±0.04	3.265±0.05	1.687±0.01	2.031±0.03	2.025±0.03	2.031±0.02	
3	6.481±0.05	6.314±0.03	7.295±0.03	6.328±0.06	6.609±0.02	7.037±0.12	6.488±0.11	6.961±0.08	4.952±0.07	5.476±0.09	5.998±0.12	5.678±0.10	
5	9.706±0.02	8.644±0.09	7.425±0.02	7.235±0.03	10.000±0.09	10.303±0.19	9.753±0.06	9.596±0.05	7.370±0.06	7.655±0.15	7.873±0.03	7.958±0.09	
CL-MB-9													
1	2.267±0.03	1.763±0.02	0.896±0.02	1.658±0.01	2.034±0.01	2.486±0.03	2.136±0.01	2.691±0.04	1.612±0.03	1.873±0.02	2.005±0.05	1.961±0.04	
3	5.789±0.10	1.665±0.02	5.111±0.01	4.732±0.02	6.101±0.09	6.900±0.07	6.344±0.02	6.393±0.03	4.473±0.04	5.343±0.10	5.678±0.10	5.550±0.08	
5	9.579±0.18	9.131±0.01	9.385±0.05	6.665±0.08	9.317±0.05	9.654±0.10	9.713±0.14	9.117±0.06	6.934±0.08	7.410±0.07	7.388±0.05	7.496±0.12	
CL-MB-10													
1	2.253±0.01	1.757±0.02	1.426±0.02	1.261±0.02	2.036±0.02	2.478±0.02	2.085±0.02	2.473±0.04	1.608±0.04	1.698±0.03	1.985±0.06	1.916±0.02	
3	5.042±0.02	4.937±0.01	4.875±0.01	1.226±0.02	6.102±0.02	6.897±0.04	5.865±0.07	6.240±0.04	4.336±0.03	5.269±0.02	5.550±0.08	5.490±0.10	
5	7.568±0.10	7.609±0.06	7.228±0.02	4.653±0.03	8.286±0.07	8.358±0.12	8.313±0.06	8.632±0.08	6.398±0.07	6.777±0.03	6.829±0.09	6.836±0.12	

Table 3.8 (cont.) Viscosity of CL-MBs with varied conditions compared with CMMS, cross-linked MB and 4-commercial polymers in the alcohol solution

Conc. (% w/v)	Viscosity (Pa.s)											
	EtOH:H ₂ O (0:100)			EtOH:H ₂ O (30:70)			EtOH:H ₂ O (50:50)					
	Freshly prep.	FT cycle	8°C	45°C	Freshly prep.	FT cycle	8°C	45°C	Freshly prep.	FT cycle	8°C	45°C
Carbopol 940 (CP)												
0.5	12.995±0.18	12.416±0.16	12.825±0.11	5.727±0.11	13.108±0.02	13.404±0.25	21.572±0.37	11.963±0.27	9.987±0.13	10.881±0.22	10.218±0.16	10.218±0.16
1	13.304±0.24	14.827±0.30	15.818±0.29	8.384±0.11	14.250±0.23	15.139±0.31	14.349±0.24	15.506±0.16	11.265±0.08	14.066±0.19	13.798±0.13	13.798±0.13
Methylcellulose (MC)												
2	2.964±0.04	2.762±0.03	2.658±0.02	2.709±0.02	5.612±0.11	3.513±0.04	4.960±0.09	4.482±0.05	4.113±0.04	5.352±0.04	5.353±0.09	5.353±0.09
3	6.701±0.13	7.528±0.02	6.519±0.05	6.493±0.07	9.988±0.12	9.361±0.06	9.990±0.13	9.168±0.15	9.142±0.09	13.031±0.21	11.521±0.10	11.521±0.10
4	12.034±0.16	11.696±0.18	11.809±0.06	11.899±0.21	16.217±0.03	15.408±0.19	15.202±0.28	17.884±0.18	15.103±0.02	17.834±0.22	18.445±0.18	18.445±0.19
5	16.903±0.15	17.499±0.06	17.971±0.17	14.358±0.05	23.504±0.21	24.416±0.49	21.572±0.37	24.633±0.43	19.115±0.30	20.538±0.38	20.364±0.38	20.364±0.38
Hydroxypropylmethylcellulose (HPMC)												
2	2.003±0.03	2.848 ±0.05	2.733 ±0.03	1.938±0.09	2.752±0.03	3.435±0.06	3.440±0.05	2.976±0.01	5.489±0.01	6.889±0.04	5.746±0.01	5.746±0.01
3	5.074±0.04	7.423±0.11	7.411±0.12	4.260±0.04	11.609±0.13	12.255±0.19	10.995±0.06	10.586±0.12	9.008±0.05	13.551±0.11	10.721±0.12	10.721±0.12
4	10.482±0.16	10.173±0.12	12.391±0.14	12.126±0.05	19.128±0.38	17.309±0.33	16.401±0.18	20.618±0.83	16.681±0.11	15.348±0.23	11.522±0.23	11.522±0.23
5	13.616±0.28	12.287±0.25	14.000±0.23	14.620±0.27	20.594±0.39	21.427±0.40	21.922±0.41	22.902±0.29	13.590±0.08	14.775±0.22	13.404±0.17	13.404±0.17

Table 3.8 (cont.) Viscosity of CL-MBs with varied conditions compared with CMMS, cross-linked MB and 4-commercial polymers in the alcohol solution

Conc. (% w/v)		Viscosity (Pa.s)											
		EtOH:H ₂ O (0:100)			EtOH:H ₂ O (30:70)			EtOH:H ₂ O (50:50)					
		Freshly prep.	FT cycle	8°C	45°C	Freshly prep.	FT cycle	8°C	45°C	Freshly prep.	FT cycle	8°C	45°C
Sodium carboxymethylcellulose (SCMC)													
2	2.416±0.02	1.983±0.02	1.570±0.02	1.851 ±0.03	4.814±0.02	5.333±0.06	4.808±0.07	4.926±0.12	5.658±0.07	5.464±0.03	4.942±0.07	4.942±0.07	4.942±0.07
3	4.175±0.05	3.604±0.04	1.911±0.04	3.587±0.01	9.720±0.08	10.099±0.13	6.907±0.14	10.474±0.20	8.282±0.03	9.784±0.17	9.851±0.16	9.851±0.16	9.851±0.16
4	9.476±0.09	8.067±0.15	6.389±0.12	8.634±0.23	12.690±0.08	14.485±0.27	15.454±0.14	13.385±0.24	10.590±0.09	12.128±0.08	11.264±0.17	11.264±0.17	11.264±0.17
5	12.935±0.07	11.944±0.10	10.329±0.08	11.366±0.08	16.031±0.04	15.354±0.19	16.616±0.18	16.387±0.03	13.664±0.21	13.258±0.30	13.664±0.21	13.664±0.21	13.664±0.21

Table 3.9 Clarity of CL-MBs with varied conditions compared with CMMS, cross-linked MB and 4-commercial polymers in the alcohol solution

Conc. (% w/v)		Clarity (Absorbance, A)											
		EtOH:H ₂ O (0:100)				EtOH:H ₂ O (30:70)				EtOH:H ₂ O (50:50)			
		Freshly prep.	FT cycle	8°C	45°C	Freshly prep.	FT cycle	8°C	45°C	Freshly prep.	FT cycle	8°C	45°C
C-MB-100													
1	0.217±0.0004	0.059±0.0000	N/A	N/A	N/A	0.367±0.0001	0.232±0.0000	0.292±0.0000	0.326±0.0001	1.046±0.0005	0.235±0.0000	0.383±0.0001	0.388±0.0006
3	0.619±0.0000	0.064±0.0004	N/A	N/A	N/A	0.839±0.0004	0.902±0.0004	0.683±0.0000	0.786±0.0006	1.219±0.0004	1.125±0.0004	1.090±0.0000	1.125±0.0008
5	1.146±0.0005	0.829±0.0005	N/A	N/A	N/A	1.329±0.0005	1.557±0.0008	1.232±0.0002	1.125±0.0013	2.197±0.0009	1.891±0.0008	1.723±0.0002	1.857±0.0002
L-MB-100													
1	2.018±0.0025	2.071±0.0027	1.972±0.0837	1.982±0.0000	1.982±0.0000	2.031±0.0027	2.084±0.0026	2.029±0.0034	2.054±0.0114	2.324±0.0013	2.166±0.0022	2.116±0.0069	2.564±0.0047
3	2.981±0.0071	3.042±0.0133	2.967±0.0012	2.985±0.0384	2.985±0.0384	2.985±0.0058	3.071±0.0072	2.867±0.0000	2.959±0.0040	2.984±0.0071	3.085±0.0088	2.852±0.0015	2.968±0.0242
5	3.049±0.0085	3.082±0.0115	2.911±0.0000	2.975±0.0003	2.975±0.0003	3.158±0.0089	3.204±0.0025	2.922±0.0032	2.959±0.0002	3.149±0.0085	3.174±0.0556	2.998±0.0009	3.012±0.0002
CL-MB-1													
1	0.423±0.0004	N/A	N/A	N/A	N/A	0.394±0.0005	0.436±0.0005	0.345±0.0000	0.344±0.0000	0.304±0.0005	0.578±0.0000	0.463±0.0000	0.488±0.0010
3	0.598±0.0000	N/A	N/A	N/A	N/A	0.807±0.0435	1.112±0.0004	0.721±0.0008	0.688±0.0018	1.694±0.0011	1.567±0.0005	1.424±0.0001	1.257±0.0186
5	0.844±0.0005	0.475±0.0000	N/A	N/A	N/A	1.429±0.0013	1.525±0.0005	1.101±0.0000	1.113±0.0051	2.216±0.0022	1.888±0.0005	1.814±0.0001	2.018±0.0002

Table 3.9 (cont.) Clarity of CL-MBs with varied conditions compared with CMMS, cross-linked MB and 4-commercial polymers in the alcohol solution

Conc. (% w/v)	Clarity (Absorbance, A)											
	EtOH:H ₂ O (0:100)			EtOH:H ₂ O (30:70)			EtOH:H ₂ O (50:50)					
	Freshly prep.	FT cycle	8°C	45°C	Freshly prep.	FT cycle	8°C	45°C	Freshly prep.	FT cycle	8°C	45°C
CL-MB-4												
1	0.345±0.1586	0.123±0.0004	0.064±0.0000	N/A	0.348±0.0004	0.358±0.0005	0.283±0.0000	0.312±0.0002	0.444±0.0004	0.443±0.0025	0.380±0.0001	0.371±0.0000
3	0.595±0.0000	0.184±0.0000	0.095±0.0006	0.272±0.0303	0.610±0.0000	1.019±0.0005	0.701±0.0000	0.682±0.0055	1.370±0.0004	1.452±0.0007	1.108±0.0001	1.025±0.0004
5	0.818±0.0005	0.704±0.0000	0.220±0.0000	N/A	1.043±0.0005	1.284±0.0005	0.981±0.0001	1.069±0.1013	2.118±0.0005	1.811±0.0009	1.619±0.0002	1.456±0.0005
CL-MB-5												
1	0.251±0.0000	0.156±0.0002	0.112±0.0000	0.090±0.0002	0.319±0.0000	0.347±0.0038	0.278±0.0001	0.253±0.0036	0.423±0.0004	0.366±0.0004	0.373±0.0039	0.325±0.0001
3	0.554±0.0000	0.252±0.0001	0.098±0.0003	0.188±0.0003	0.571±0.0004	0.793±0.0004	0.701±0.0001	0.653±0.0006	1.019±0.0000	1.366±0.0007	1.049±0.0001	0.788±0.0002
5	0.807±0.0005	0.726±0.0000	0.134±0.0001	0.488±0.0010	1.002±0.0004	1.102±0.0005	0.879±0.0001	0.856±0.0006	1.927±0.0005	1.726±0.0005	1.602±0.0002	1.370±0.0001
CL-MB-7												
1	0.236±0.0004	0.075±0.0000	0.215±0.0000	0.162±0.0001	0.262±0.0004	0.217±0.0000	0.223±0.0000	0.164±0.0001	0.288±0.0143	0.325±0.0000	0.275±0.0000	0.237±0.0000
3	0.315±0.0005	0.213±0.0001	0.105±0.0000	0.173±0.0000	0.541±0.0005	0.444±0.0133	0.444±0.0000	0.406±0.0080	0.850±0.0004	0.725±0.0001	0.747±0.0001	0.624±0.0001
5	0.424±0.0004	0.423±0.0001	0.112±0.0000	0.439±0.0001	0.833±0.0000	0.707±0.0101	0.651±0.0000	0.647±0.0000	1.326±0.0007	1.026±0.0005	1.096±0.0001	1.074±0.0002

Table 3.9 (cont.) Clarity of CL-MBs with varied conditions compared with CMMS, cross-linked MB and 4-commercial polymers in the alcohol solution

Conc. (% w/v)		Clarity (Absorbance, A)											
		EtOH:H ₂ O (0:100)				EtOH:H ₂ O (30:70)				EtOH:H ₂ O (50:50)			
		Freshly prep.	FT cycle	8°C	45°C	Freshly prep.	FT cycle	8°C	45°C	Freshly prep.	FT cycle	8°C	45°C
CL-MB-8													
1	0.237±0.0005	0.105±0.0000	0.246±0.0000	0.166±0.0001	0.296±0.0000	0.246±0.0000	0.225±0.0000	0.193±0.0000	0.302±0.0000	0.332±0.0000	0.300±0.0000	0.253±0.0036	
3	0.437±0.0004	0.225±0.0000	0.115±0.0000	0.183±0.0360	0.548±0.0004	0.475±0.0000	0.497±0.0001	0.473±0.0000	0.884±0.0005	0.851±0.0001	0.753±0.0000	0.650±0.0000	
5	0.493±0.0000	0.485±0.0004	0.116±0.0004	0.442±0.0000	0.849±0.0000	0.714±0.0032	0.717±0.0000	0.711±0.0001	1.537±0.0004	1.246±0.0016	1.147±0.0002	1.152±0.0005	
CL-MB-9													
1	0.350±0.0000	0.152±0.0000	0.251±0.0000	0.183±0.0000	0.390±0.0005	0.259±0.0005	0.252±0.0001	0.225±0.0000	0.347±0.0005	0.352±0.0000	0.325±0.0000	0.268±0.0004	
3	0.546±0.0000	0.258±0.0040	0.152±0.0000	0.189±0.0000	0.628±0.0004	0.486±0.0001	0.563±0.0000	0.498±0.0000	0.930±0.0005	0.878±0.0005	0.863±0.0000	0.669±0.0001	
5	0.634±0.0007	0.603±0.0048	0.644±0.0002	0.465±0.0003	0.894±0.0005	0.733±0.0000	0.747±0.0000	0.723±0.0000	1.677±0.0009	1.406±0.0004	1.342±0.0002	1.155±0.0026	
CL-MB-10													
1	0.396±0.0004	0.341±0.0010	0.189±0.0000	0.323±0.0001	0.457±0.0000	0.274±0.0000	0.227±0.0000	0.245±0.0001	0.530±0.0005	0.360±0.0000	0.332±0.0000	0.298±0.0000	
3	0.578±0.0000	0.492±0.0004	0.485±0.0005	0.191±0.0000	0.672±0.0000	0.647±0.0004	0.645±0.0000	0.509±0.0000	0.965±0.0008	1.220±0.0004	0.990±0.0001	0.689±0.0000	
5	0.831±0.0004	0.690±0.0005	0.572±0.0000	0.634±0.0029	0.993±0.0004	1.079±0.0004	0.723±0.0000	0.843±0.0006	1.999±0.0009	1.684±0.0009	1.590±0.0003	1.290±0.0001	

Table 3.9 (cont.) Clarity of CL-MBs with varied conditions compared with CMMS, cross-linked MB and 4-commercial polymers in the alcohol solution

Conc. (% w/v)		Clarity (Absorbance, A)										
		EtOH:H ₂ O (0:100)			EtOH:H ₂ O (30:70)			EtOH:H ₂ O (50:50)				
	Freshly prep.	FT cycle	8°C	45°C	Freshly prep.	FT cycle	8°C	45°C	Freshly prep.	FT cycle	8°C	45°C
Carbopol 940 (CP)												
0.5	0.053±0.0004	0.061±0.0000	0.102±0.0000	0.061±0.0000	0.297±0.0000	0.225±0.0001	0.287±0.0000	0.097±0.0000	0.453±0.0005	0.345±0.0001	0.323±0.0000	0.358±0.0001
1	0.465±0.0000	0.445±0.0004	0.189±0.0000	0.209±0.0000	0.465±0.0000	0.312±0.0001	0.316±0.0000	0.384±0.0006	0.865±0.0005	0.624±0.0001	0.603±0.0001	0.544±0.0004
Methylcellulose (MC)												
2	0.016±0.0000	0.009±0.0002	0.008±0.0000	0.015±0.0000	0.007±0.0005	0.018±0.0001	0.016±0.0000	0.022±0.0000	0.002±0.0004	0.035±0.0003	0.027±0.0000	0.024±0.0000
3	0.018±0.0005	0.019±0.0002	0.017±0.0000	0.021±0.0000	0.018±0.0000	0.026±0.0002	0.021±0.0000	0.040±0.0000	0.026±0.0000	0.037±0.0000	0.030±0.0000	0.044±0.0000
4	0.019±0.0000	0.024±0.0000	0.020±0.0000	0.035±0.0000	0.024±0.0004	0.039±0.0002	0.028±0.0000	0.041±0.0001	0.030±0.0000	0.040±0.0000	0.037±0.0000	0.053±0.0001
5	0.030±0.0005	0.042±0.0013	0.037±0.0000	0.039±0.0000	0.034±0.0000	0.054±0.0000	0.040±0.0001	0.042±0.0000	0.075±0.0004	0.063±0.0000	0.043±0.0000	0.054±0.0000
Hydroxypropylmethylcellulose (HPMC)												
2	0.128±0.0004	0.015±0.0000	0.019±0.0001	0.038±0.0001	0.382±0.0004	0.152±0.0001	0.122±0.0000	0.097±0.0015	0.561±0.0000	0.248±0.0891	0.293±0.0000	0.103±0.0000
3	0.224±0.0000	0.029±0.0001	0.025±0.0000	0.043±0.0000	0.415±0.0004	0.386±0.0001	0.389±0.0000	0.380±0.0005	0.786±0.0004	0.384±0.0005	0.328±0.0000	0.141±0.0000
4	0.616±0.0005	0.047±0.0002	0.046±0.0000	0.084±0.0001	0.694±0.0004	0.624±0.0001	0.358±0.0001	0.655±0.0001	1.059±0.0005	0.517±0.0001	0.517±0.0001	0.722±0.0000
5	0.704±0.0004	0.045±0.0001	0.066±0.0000	0.586±0.0002	0.713±0.0004	0.738±0.0024	0.613±0.0001	0.867±0.0019	1.358±0.0004	0.724±0.0000	0.649±0.0000	0.917±0.0000

Table 3.9 (cont.) Clarity of CL-MBs with varied conditions compared with CMMS, cross-linked MB and 4-commercial polymers in the alcohol solution

Conc. (% w/v)		Clarity (Absorbance, A)											
		EtOH:H ₂ O (0:100)				EtOH:H ₂ O (30:70)				EtOH:H ₂ O (50:50)			
		Freshly prep.	FT cycle	8°C	45°C	Freshly prep.	FT cycle	8°C	45°C	Freshly prep.	FT cycle	8°C	45°C
Sodium carboxymethylcellulose (SCMC)													
2	0.022±0.0000	0.012±0.0000	0.014±0.0001	0.025±0.0000	0.024±0.0005	0.021±0.0000	0.021±0.0000	0.021±0.0000	0.038±0.0001	0.075±0.0000	0.057±0.0000	0.047±0.0001	0.084±0.0000
3	0.030±0.0004	0.267±0.1308	0.031±0.0000	0.026±0.0000	0.139±0.0000	0.120±0.0001	0.087±0.0000	0.120±0.0000	0.120±0.0000	0.157±0.0005	0.237±0.0000	0.206±0.0000	0.145±0.0000
4	0.034±0.0000	0.054±0.0013	0.053±0.0000	0.058±0.0000	0.178±0.0005	0.265±0.0000	0.253±0.0001	0.265±0.0000	0.265±0.0000	0.744±0.0000	0.505±0.0000	0.505±0.0000	0.466±0.0001
5	0.134±0.0000	0.476±0.0000	0.091±0.0000	0.066±0.0000	0.259±0.0004	0.286±0.0002	0.439±0.0001	0.288±0.0000	0.288±0.0000	0.751±0.0004	1.064±0.0000	0.548±0.0001	0.549±0.0021

Table 3.10 pH of CL-MBs with varied conditions compared with CMMS, cross-linked MB and 4-commercial polymers in the alcohol solution

Conc. (% w/v)		pH											
		EtOH:H ₂ O (0:100)				EtOH:H ₂ O (30:70)				EtOH:H ₂ O (50:50)			
		Freshly prep.	FT cycle	8°C	45°C	Freshly prep.	FT cycle	8°C	45°C	Freshly prep.	FT cycle	8°C	45°C
C-MB-100													
1	7.2	6.8	N/A	N/A	7.0	6.9	6.9	6.9	7.1	7.0	6.9	6.8	
3	7.1	6.8	N/A	N/A	7.1	7.0	7.1	7.0	7.0	6.9	7.0	6.8	
5	7.1	6.9	N/A	N/A	7.0	6.9	6.9	7.0	7.2	7.2	6.9	7.1	
L-MB-100													
1	6.9	6.9	7.0	6.9	7.0	7.0	6.9	7.0	7.0	6.9	6.9	7.0	
3	6.9	6.9	7.0	7.0	7.0	7.0	6.9	7.0	7.0	7.0	7.1	7.0	
5	7.0	6.9	7.0	7.0	7.0	7.0	7.0	7.0	7.0	6.8	7.0	7.0	
CL-MB-1													
1	6.8	N/A	N/A	N/A	6.9	6.9	7.0	7.0	7.1	6.9	7.0	7.0	
3	6.8	N/A	N/A	N/A	7.0	6.9	7.1	7.1	7.1	7.0	7.2	7.0	
5	6.9	7.0	N/A	N/A	7.0	6.9	6.88	6.9	7.0	6.8	6.9	7.0	

Table 3.10 (cont.) pH of CL-MBs with varied conditions compared with CMMS, cross-linked MB and 4-commercial polymers in the alcohol solution

Conc. (% w/v)		pH											
		EtOH:H ₂ O (0:100)				EtOH:H ₂ O (30:70)				EtOH:H ₂ O (50:50)			
		Freshly prep.	FT cycle	8°C	45°C	Freshly prep.	FT cycle	8°C	45°C	Freshly prep.	FT cycle	8°C	45°C
CL-MB-4													
1	6.9	6.8	6.9	N/A	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.2
3	6.9	6.8	6.9	7.2	7.0	7.0	6.8	7.0	7.0	6.9	7.1	7.0	7.0
5	6.8	6.9	6.9	N/A	7.1	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0
CL-MB-5													
1	6.8	6.8	6.9	6.8	7.0	7.0	6.9	7.0	7.0	7.0	6.9	7.0	6.8
3	6.9	6.9	6.9	7.0	7.0	7.1	7.0	7.1	7.1	7.0	7.0	6.9	6.8
5	6.8	6.9	7.0	7.1	7.0	7.0	6.8	7.0	7.0	7.0	7.0	7.0	6.8
CL-MB-7													
1	7.2	7.1	7.2	7.0	7.1	7.1	7.0	7.1	7.1	7.1	7.2	7.1	7.2
3	7.2	7.1	7.2	7.0	7.1	7.1	7.0	7.1	7.1	7.0	7.1	7.1	7.1
5	7.1	7.2	7.2	7.1	7.0	7.1	7.2	7.2	7.2	7.2	7.1	7.1	7.1

Table 3.10 (cont.) pH of CL-MBs with varied conditions compared with CMMS, cross-linked MB and 4-commercial polymers in the alcohol solution

Conc. (% w/v)		pH											
		EtOH:H ₂ O (0:100)				EtOH:H ₂ O (30:70)				EtOH:H ₂ O (50:50)			
		Freshly prep.	FT cycle	8°C	45°C	Freshly prep.	FT cycle	8°C	45°C	Freshly prep.	FT cycle	8°C	45°C
CL-MB-8													
1	7.0	6.9	6.9	6.8	6.9	6.9	7.0	7.1	7.1	7.1	6.9	6.9	6.8
3	7.1	7.0	6.9	6.8	7.0	6.8	6.9	7.0	7.0	7.0	6.9	7.0	6.8
5	7.0	7.0	6.9	7.0	6.9	7.1	6.9	7.1	7.1	7.0	7.0	7.0	6.9
CL-MB-9													
1	6.9	6.9	6.9	6.8	6.8	7.0	6.8	6.9	6.9	6.9	7.0	7.0	6.8
3	7.0	7.0	6.9	6.8	7.1	7.0	7.0	6.8	6.8	7.1	6.8	6.9	7.0
5	6.9	7.1	7.0	6.9	6.9	7.1	7.0	7.0	7.0	6.9	7.0	7.0	7.2
CL-MB-10													
1	6.9	6.9	6.8	6.9	6.9	6.9	6.9	6.8	6.8	6.8	6.9	6.8	7.0
3	7.0	6.8	6.8	6.9	6.8	6.9	7.0	6.8	6.8	6.9	7.0	7.0	7.1
5	6.9	7.0	7.2	6.9	6.8	6.9	7.1	6.9	6.9	7.1	6.9	6.8	6.8

Table 3.10 (cont.) pH of CL-MBs with varied conditions compared with CMMS, cross-linked MB and 4-commercial polymers in the alcohol solution

Conc. (% w/v)		pH											
		EtOH:H ₂ O (0:100)				EtOH:H ₂ O (30:70)				EtOH:H ₂ O (50:50)			
		Freshly prep.	FT cycle	8°C	45°C	Freshly prep.	FT cycle	8°C	45°C	Freshly prep.	FT cycle	8°C	45°C
Carbopol 940 (CP)													
0.5	7.4	7.5	7.4	7.4	7.4	7.4	7.4	7.5	7.5	7.4	7.4	7.4	7.4
1	7.5	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.5	7.4	7.4	7.4
Methylcellulose (MC)													
2	6.9	7.0	7.1	6.9	7.0	6.9	7.0	7.1	6.9	7.0	7.0	7.2	7.2
3	6.8	7.0	6.9	7.0	6.9	6.8	6.8	6.8	7.1	6.8	6.8	6.8	7.0
4	7.0	6.9	7.1	7.0	6.8	6.9	7.1	6.8	7.1	7.0	7.1	7.1	7.1
5	7.1	7.0	7.0	6.9	7.2	7.2	7.1	7.0	7.1	7.1	7.1	7.1	6.9
Hydroxypropylmethylcellulose (HPMC)													
2	6.8	7.0	6.8	7.1	6.9	6.8	6.8	6.8	6.9	6.8	7.0	6.8	6.8
3	6.7	6.9	6.9	6.7	6.8	7.0	6.9	6.9	7.1	7.0	7.0	7.0	6.9
4	6.8	7.0	6.9	6.9	6.9	6.9	7.1	6.9	7.0	6.9	7.0	7.0	7.0
5	7.2	7.1	7.0	7.1	6.9	6.9	6.8	6.8	6.9	6.8	6.9	6.8	7.1

Table 3.10 (cont.) pH of CL-MBs with varied conditions compared with CMMS, cross-linked MB and 4-commercial polymers in the alcohol solution

Conc. (% w/v)		pH											
		EtOH:H ₂ O (0:100)			EtOH:H ₂ O (30:70)			EtOH:H ₂ O (50:50)					
		Freshly prep.	8°C	45°C	Freshly prep.	FT cycle	8°C	45°C	Freshly prep.	FT cycle	8°C	45°C	
Sodium carboxymethylcellulose (SCMC)													
2	6.9	6.9	7.1	6.9	7.1	6.9	6.8	6.8	6.9	7.1	7.0	7.0	
3	6.8	6.7	6.9	7.0	7.0	7.1	6.8	6.9	6.8	6.9	6.8	6.9	
4	6.8	7.1	7.0	6.9	6.9	7.0	7.0	6.8	7.1	7.0	6.9	7.0	
5	6.9	6.8	6.9	7.0	7.0	7.0	7.1	7.0	6.9	7.0	7.0	6.8	

The clarity of CL-MBs gel at 700 nm is presented in Table 3.9A-3.9E. The clarity of CL-MB-7 gel in distilled water was significantly less than that of the four commercial polymers, but was similar to that of CMMS, and slightly changed at 8°C and 45°C and when tested for HC cycle stability. The clarity of CL-MB decreased at high concentrations, similar to CMMS. The clarity of CL-MB in an EtOH: H₂O solution of ratio 0:100, 30:70 and 50:50 and at 1, 3 and 5%w/v, slightly increased. The CL-MB gels that exhibited the best clarity were CL-MB-7, CL-MB-8 and CL-MB-9. Their clarity changed slightly after a stability test at 8°C and 45°C, and an HC cycle stability (not significant). The cross-linked MB showed a very high absorbance level, because it is insoluble in water and EtOH. However, the clarity of the CL-MB gels was better than for the CMMS gel.

Table 3.10A-3.10E, the pH of CL-MBs gel at 1, 3 and 5%w/v in 3 media: an EtOH: H₂O mix of ratio 0:100, 30:70 and 50:50, was 6.8 to 7.4. In the experiment, the pH of CL-MBs paste was not changed by EtOH when stored in 8°C and 45°C and when tested for HC cycle stability. So, the alcohol was non effect to the clarity of CL-MBs in the same as four commercial polymers.

3.6 Selection of Cross-linked carboxymethyl modified mungbean

From the physicochemical properties and alcohol tolerability, the three best cross-linked carboxymethyl modified mungbean starch (CL-MBs) were chosen to use in the formulation of NM gel. CL-MB-7, CL-MB-8 and CL-MB-9 exhibited good gel characteristics, which suggested the potential use of CL-MBs as a new gelling biopolymer for pharmaceutical application.

3.7 Nimesulide gel formulation

3.7.1 Nimesulide gel preformulation

The preliminary batches were formulated by varying the concentration of gelling agent and other excipients. Nimesulide (C₁₃H₁₂N₂O₅S) were kept constant at 1%w/w, as an active ingredient. Each material was weighed accurately and added on the order by mixing. Three-chosen CL-MBs and commercial polymers (CP and SCMC) were used as a gelling agent in the formulation. The gelling agent was dispersed in the distilled water at the concentration in the formula. The suspension

was stirred and allowed to stand over night at room temperature in order to be completely swelling.

NM gel was formulated by the order-of-mixing technique. Nimesulide (NM) was used as an active ingredient in the gel formulation. Three-chosen and commercial polymers (CP and SCMC) were used as a gelling agent. Dimethyl sulfoxide (DMSO) and denatured ethanol (DEB 96) were used as a solvent. DMSO was a penetration enhancer. Propylene glycol was used as a humectant and triethanolamine (TEA) as a pH adjuster. Methyl paraben and propyl paraben were added as a preservatives.



Figure 3.17 – Nimesulide gel preparation

In the experiment, Part 1: NM was dissolved in the mixture of DMSO and DEB 96 to be yellowish (Figure 3.17A-3.17B). TEA was added into the solution and mixed to be the amber-colored solution (Figure 3.17C). Part 2: the humectant (Propylene glycol) and TEA were added into the polymer gel and mixing the mixture by stirring to be a homogeneous mixture (Figure 3.17D). Afterward, Part 1 was added slowly together with Part 2 and stirred continuously to protect the foaming from the polymer (Figure 3.17E). The preservative (Paraben conc.) was add into the

homogeneous mixture. NM gel was stored in the well-tight container. The formula (recipe) was shown in Table 3.10.

The specification of nimesulide gel : 1 g of nimesulide was contained in 100 g of the gel formulation (1%w/w of nimesulide).

- Appearance : amber-colored gel
- Identification : the formulation contains nimesulide (active ingredient)
- pH (10%w/w nimesulide gel in distilled water) : 5.5-8.5
- Assay of active ingredient :

Labeled amount : each 1 g of the gel formulation contains 10 mg nimesulide

Limit : 0.09-1.10%w/w of nimesulide

Table 3.11, F1-F12 formulations were prepared by using CL-MBs as a gelling agent. On the contrary, the gelling agent was incorporated in F13-F15 as commercial polymers: CP and SCMC, respectively (Figure 3.19). Nimesulide was soluble in DMSO. It showed recrystallization after it was incorporated in NM preparation (Figure 3.18). So, the formulation that varied DMSO and DEB 96 were shown in F1-F8. The F8 showed less crystallization of NM and the good characteristic. Thus, TEA was added into F8 to be used as a pH adjuster in order to increase the dissolution of NM and the concentration of the gelling agent was increased. F9-F12 were developed by varied TEA and CL-MBs concentration. The F12 exhibited good gel characteristics of the NM gel formulation. Therefore, the NM gel formulation was prepared by using the additives in the same as F12 which the choosing CL-MBs in above: CL-MB-7, CL-MB-8 and CL-MB-9 and commercial polymers. The recrystallization of NM was manifested in the formulation with CP as a gelling agent but these problem was unaffected to SCMC. All formulation were studied the physicochemical properties and releasing study.

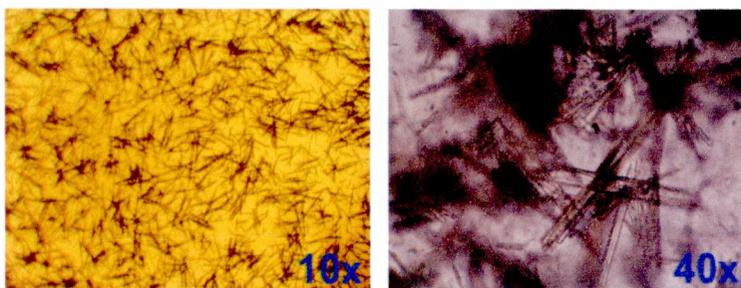


Figure 3.18 Recrystallization of nimesulide in the gel formulation

Table 3.11 Nimesulide gel preformulation by cross-linked carboxymethyl modified mungbean starch compared with commercial polymers

Ingredients (g.)	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	F14	F15
Nimesulide	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Polymer															
CL-MBs	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	5.00	5.00	5.00	6.00	-	-	-
CP	-	-	-	-	-	-	-	-	-	-	-	-	1.00	0.50	-
SCMC	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.00
DEB 96	10.00	12.00	12.00	12.00	12.00	12.00	15.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00
DMSO	2.50	4.50	6.50	8.50	10.00	15.00	15.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00
Propylene glycol	8.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00
TEA	-	-	-	-	-	-	-	-	1.65	2.50	3.50	3.50	3.50	3.50	3.50
Paraben conc.	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Purified water	73.50	67.50	65.50	63.50	62.00	57.00	55.00	52.00	48.35	47.50	46.50	45.50	50.50	51.00	45.50
Total (g.)	100.00														

Remark : The mix of methyl paraben:propyl paraben at the ratio 10:2 in propylene glycol was called Paraben conc.

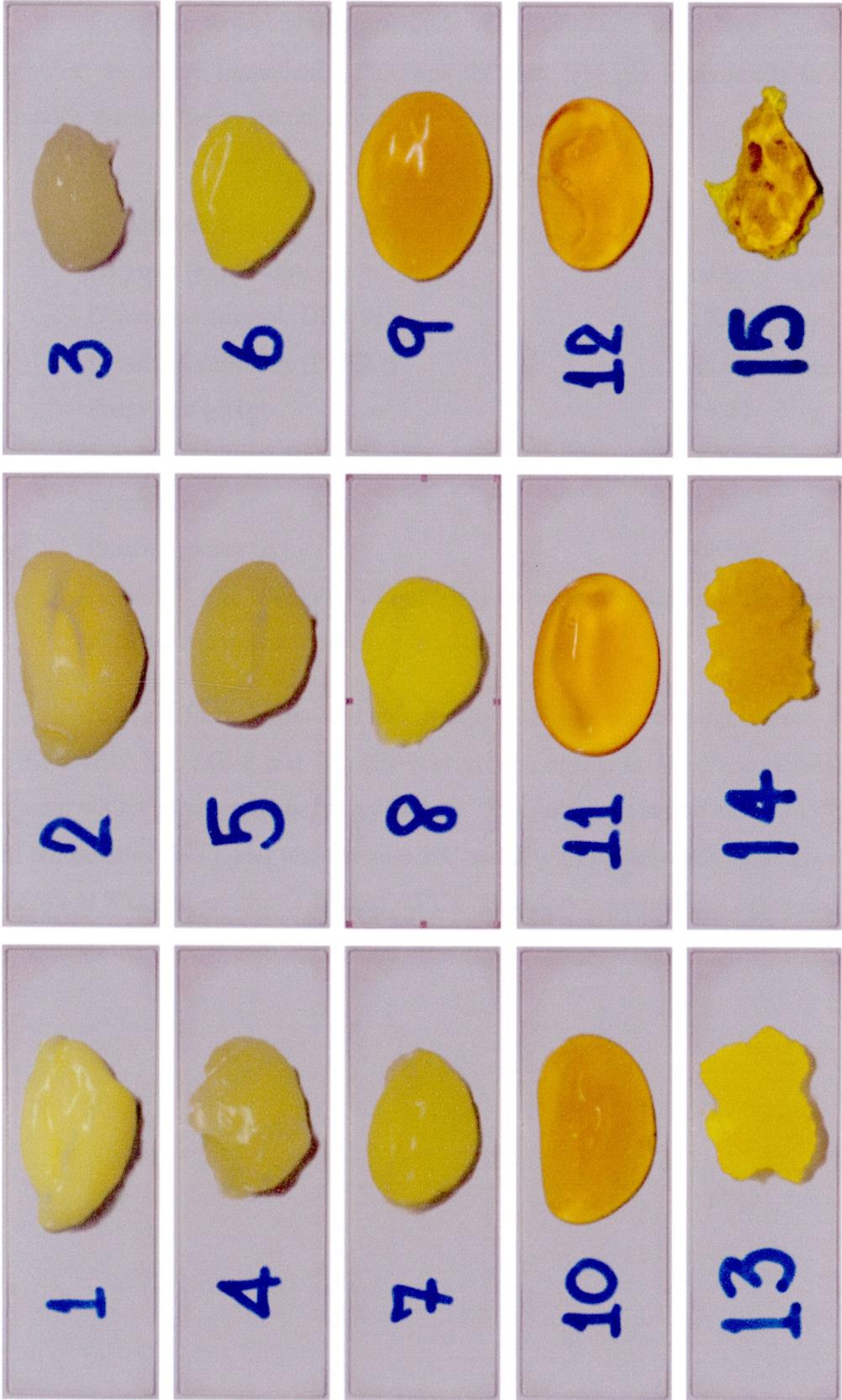


Figure 3.19 Nimesulide gel preformulations

3.7.2 Nimesulide gel formulation

From the experiment, nimesulide ($C_{13}H_{12}N_2O_5S$) were kept constant at 1%w/w, as an active ingredient. F12 was the best NM gel formulation that was continually studied the physicochemical properties and stability test.

Nimesulide gel formulation

Nimesulide	1.00	g.
Polymer (as a gelling agent)	6.00	g.
Denatured ethanol (DEB 96)	12.00	g.
Dimethyl sulfoxide (DMSO)	20.00	g.
Propylene glycol	10.00	g.
Triethanlamine (TEA)	3.50	g.
Paraben conc.	2.00	g.
Purified water qs to	100.00	g.

Remark : CL-MB-7, CL-MB-8 and CL-MB-9 were used as a gelling agent, compared with the commercial polymer (SCMC)

NM gel formulation was referred to F12 in the preliminary test. These used CL-MB-7, CL-MB-8 and CL-MB-9 as gelling agents at 6%w/v concentration, compared with a commercial polymer, SCMC. The gels were stored at 8°C, 45°C and room temperature (RT), and underwent a HC stability (8 cycles—each cycle consisted of 2 days at 8°C and another 2 days at 45°C). The appearance of gel bases and NM gel formulations were shown in Figure 3.20 and 3.21, respectively.

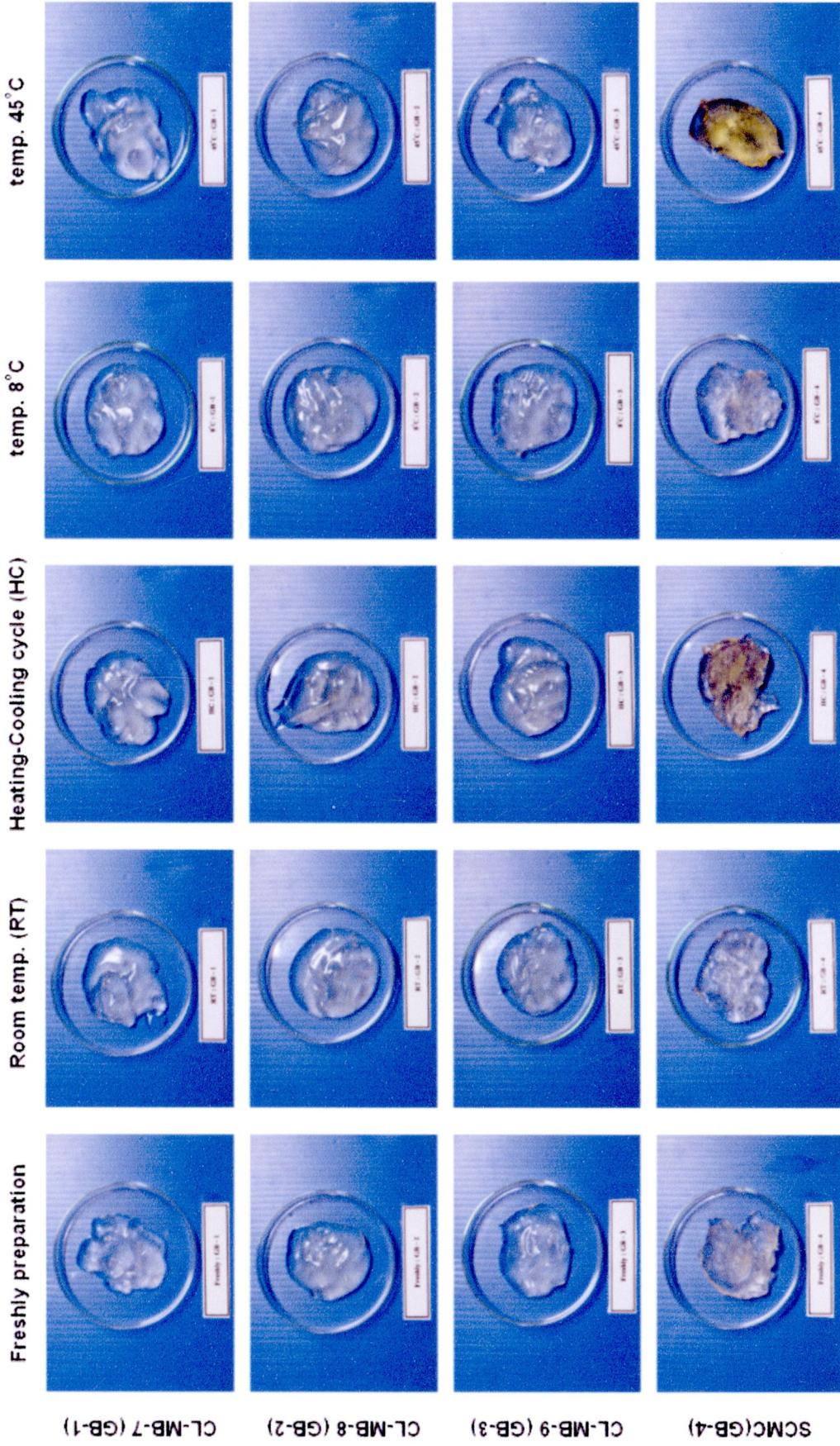


Figure 3.20 Stability of the gel base by CL-MB-7, CL-MB-8 and CL-MB-9, compared with SCMC

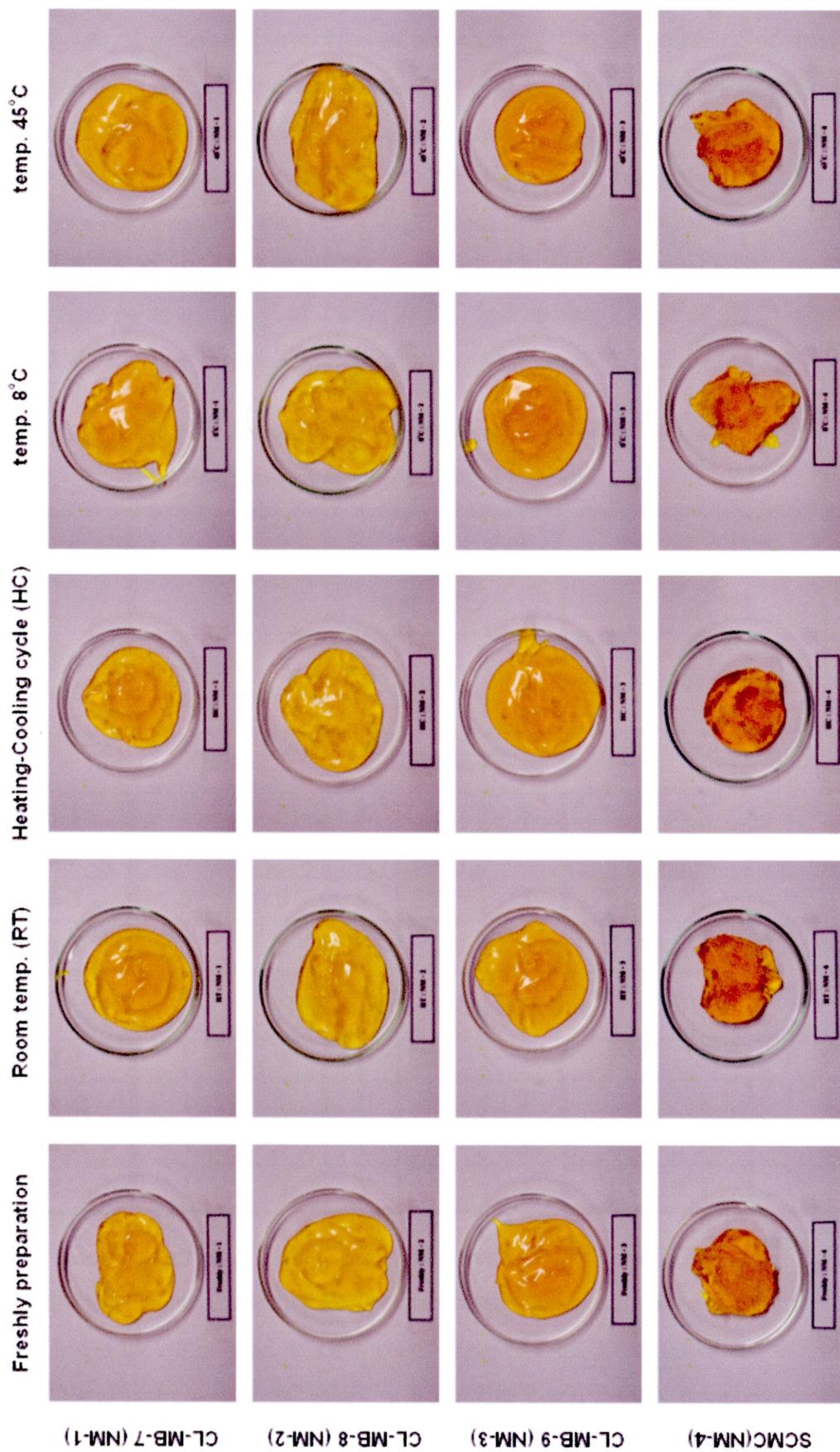


Figure 3.21 Stability of the nimesulide gel formulation by CL-MB-7, CL-MB-8 and CL-MB-9, compared with SCMC

3.8 Physicochemical properties of nimesulide gel

The physicochemical properties of nimesulide (NM) gel consisted of color, pH, gel separation, gel splitting and viscosity of all NM gel formulations with three-chosen CL-MBs and commercial polymer. The experiments was measured against the gel base with the same gelling agent. All properties of NM gel from three-chosen CL-MBs were compared with the NM gel from commercial polymer. The gel bases and formulations were stored at 8°C, 45°C and RT, and underwent a HC stability (8 cycles–each cycle consisted of 2 days at 8°C and another 2 days at 45°C), shown in Table 3.12-3.15 and Figure 3.22-3.25.

Table 3.12 Color of nimesulide gel formulation by CL-MB-7, CL-MB-8 and CL-MB-9 compared with SCMC

Preparations	Color								
	Freshly prep.	1M				3M			
		8°C	RT	45°C	HC	8°C	RT	45°C	HC
Gel base									
GB-1	5	5	5	5	5	5	5	5	5
GB-2	5	5	5	5	5	5	5	5	5
GB-3	5	5	5	5	5	5	5	5	5
GB-4	5	5	5	2	3	5	5	2	4
Nimesulide gel formulation									
NM-1	1	1	1	1	1	1	1	1	1
NM -2	1	1	1	1	1	1	1	1	1
NM -3	1	1	1	1	1	1	1	1	1
NM -4	1	1	1	1	1	1	1	1	1

Table 3.12, all of gel bases were transparent. The color of GB-1, GB-2 and GB-3 were stable at the stability test, excepted the gel base that was prepared from SCMC. On the other hand, it's color was changed after 3 months of the stability test at 45°C and underwent a HC stability from 5 to 2 and 5 to 4, respectively. So, the

color of the gel bases that were prepared from CL-MB-7, CL-MB-8 and CL-MB-9, unchanged and stable than SCMC. NM occurs as a light yellow powder. For this reason, the NM gel formulations were an amber-colored gel. After the stability test, the color of every one of NM gel formulations were unchanged. Nevertheless, the NM gel formulations were stable at all conditions.

Table 3.13 Gel separation of nimesulide gel formulation by CL-MB-7, CL-MB-8 and CL-MB-9 compared with SCMC

Preparations	Gel separation								
	Freshly prep.	1M				3M			
		8°C	RT	45°C	HC	8°C	RT	45°C	HC
Gel base									
GB-1	x	x	x	x	x	x	x	x	x
GB-2	x	x	x	x	x	x	x	x	x
GB-3	x	x	x	x	x	x	x	x	x
GB-4	x	x	x	x	x	x	x	x	x
Nimesulide gel formulation									
NM-1	x	x	x	x	x	x	x	x	x
NM-2	x	x	x	x	x	x	x	x	x
NM-3	x	x	x	x	x	x	x	x	x
NM-4	x	x	x	x	x	x	x	x	x

Remark : x = the gel base or nimesulide gel *without* separation

✓ = the gel base or nimesulide gel *with* separation

Table 3.13, all of gel bases and NM gel formulations were stable at the stability test. They were still as a gel appearance and none of the gel separation phenomenon.

Table 3.14 pH of nimesulide gel formulation by CL- MB-7, CL-MB-8 and CL-MB-9 compared with SCMC

Preparations	pH								
	Freshly prep.	1M				3M			
		8°C	RT	45°C	HC	8°C	RT	45°C	HC
Gel base									
GB-1	8.5	8.4	8.6	8.6	8.5	8.5	8.5	8.4	8.5
GB-2	8.4	8.5	8.4	8.4	8.5	8.4	8.5	8.4	8.5
GB-3	8.5	8.4	8.4	8.5	8.5	8.5	8.4	8.4	8.5
GB-4	8.4	8.4	8.4	8.3	8.3	8.4	8.3	8.5	8.4
Nimesulide gel formulation									
NM-1	8.0	7.9	7.8	7.8	7.8	7.8	7.9	7.8	7.8
NM-2	8.0	7.9	8.0	7.8	7.8	7.9	7.9	7.8	7.8
NM-3	7.8	8.0	7.9	7.8	7.8	7.9	7.8	7.8	7.8
NM-4	7.9	8.0	8.0	7.9	7.8	7.9	7.9	7.9	7.8

Table 3.14, all of gel bases and NM gel formulations were stable at the stability test. The pHs were still in the range of specification. The pH of NM gel formulations was lower than the gel bases because the active ingredient was added on. NM is a weak acidic compound. Consequently, the pH of NM gel formulations were decreased after NM was incorporated into the gel base. After the stability test, the pH of every NM gel formulations were slightly changed but they were still in the accepted range. So, the NM gel formulations were stable at all conditions.

The gel splitting test at a 40X magnification, the image of NM gel formulations were not difference from gel bases. All of gel bases (Figure 3.22) and NM gel formulations (Figure 3.23) were stable at the stability test.

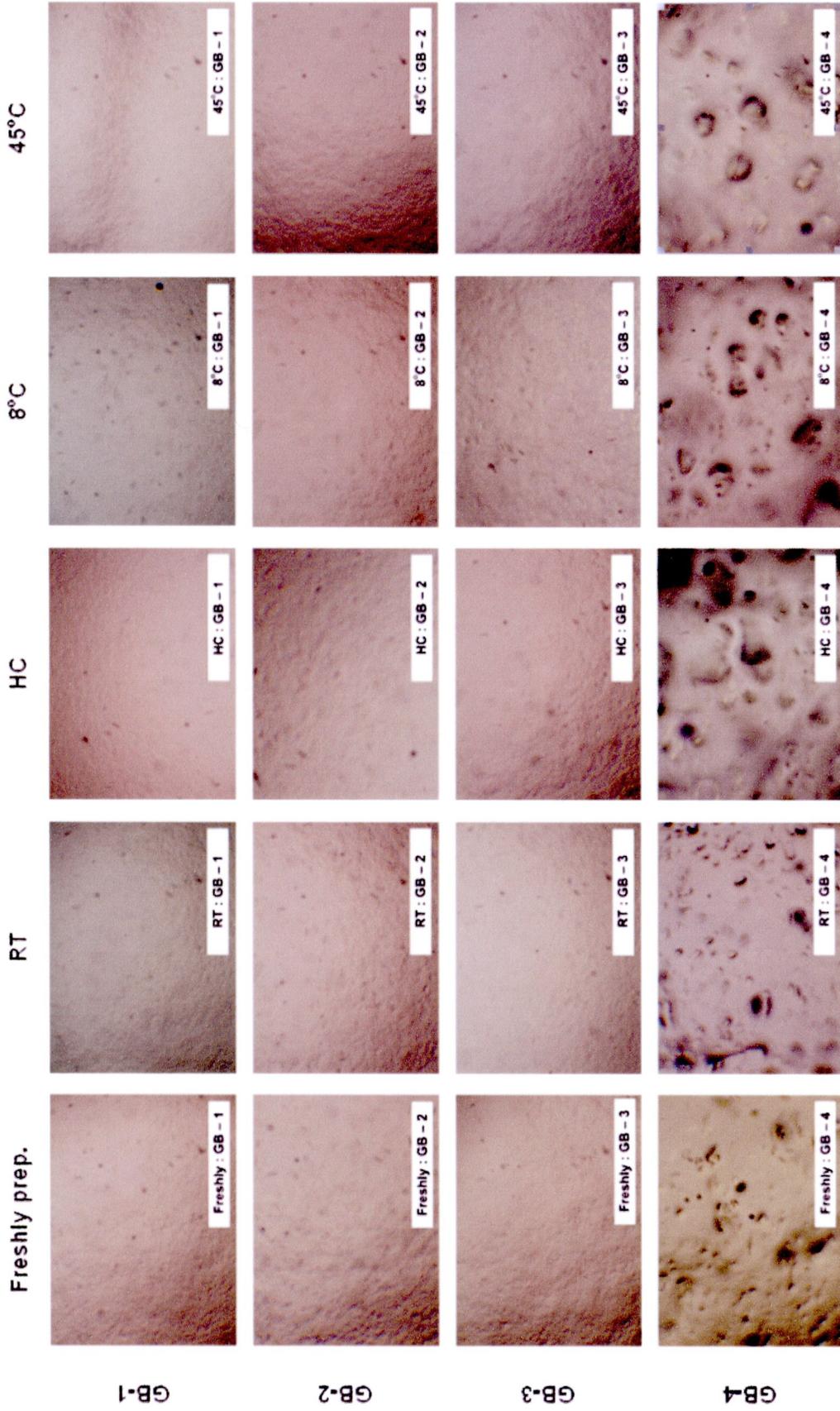


Figure 3.22 Gel splitting of gel bases by CL-MB-7, CL-MB-8, CL-MB-9, compared with SCMC in the stability test

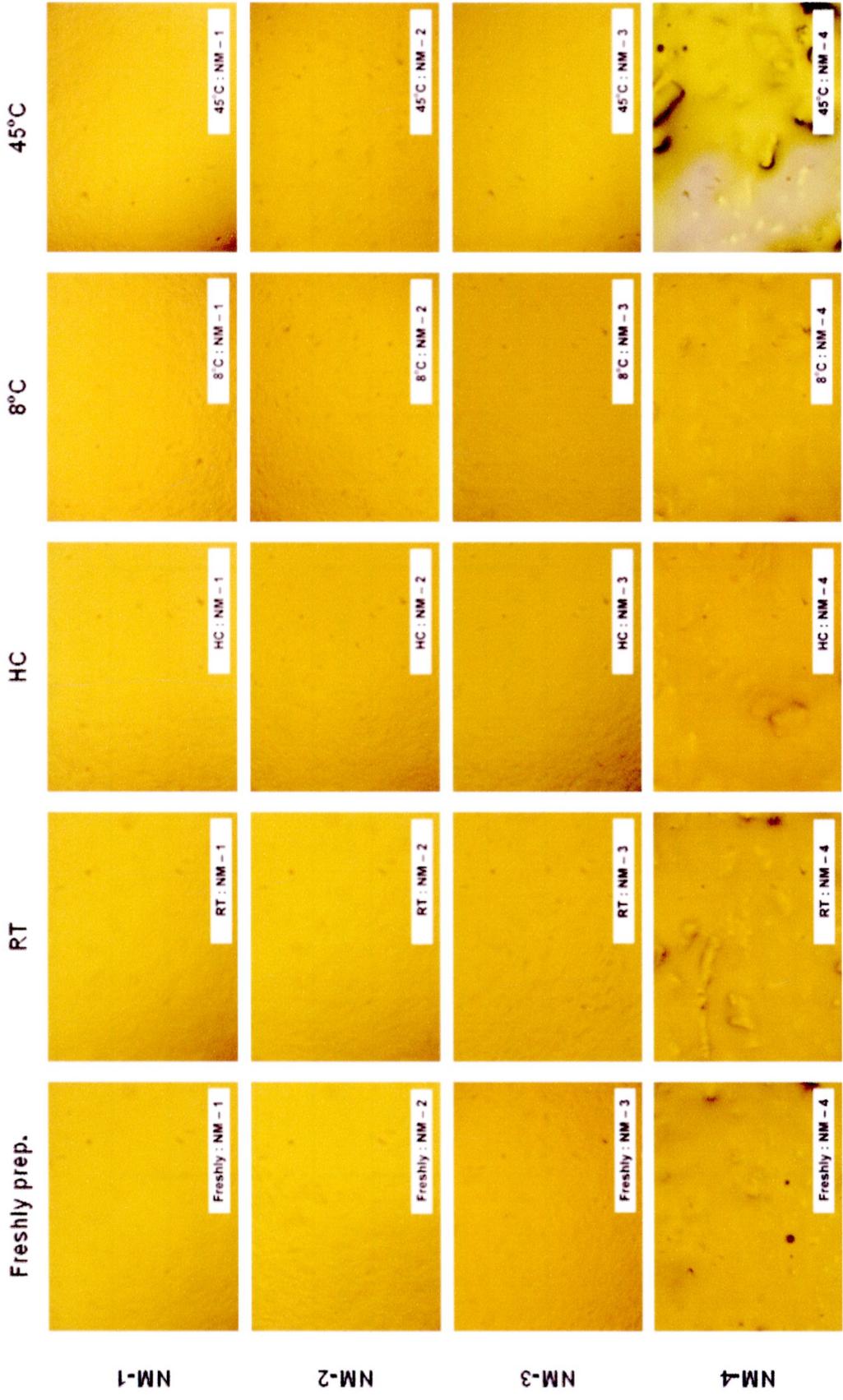


Figure 3.2.3 Gel splitting of nimesulide gel formulations by CL-MB-7, CL-MB-8, CL-MB-9, compared with SCMC in the stability test

Table 3.15 Viscosity of nimesulide gel formulation by CL-MB-7, CL-MB-8 and CL-MB-9 compared with SCMC

Preparations	Viscosity (Pa.s)									
	1M					3M				
	8°C	RT	45°C	HC	8°C	RT	45°C	HC		
Freshly prep.										
GB-1	10.590±0.04	10.526±0.02	10.672±0.02	10.406±0.04	10.595±0.03	10.634±0.03	10.401±0.03	10.440±0.02		
GB-2	11.268±0.01	11.314±0.02	11.052±0.02	10.772±0.03	11.478±0.02	11.622±0.03	11.112±0.03	10.861±0.03		
GB-3	10.354±0.06	10.247±0.04	10.379±0.03	9.745±0.09	10.565±0.03	10.267±0.03	10.041±0.03	9.717±0.03		
GB-4	19.263±0.53	19.127±0.90	18.087±0.22	19.021±0.38	20.094±0.90	19.211±0.48	18.398±0.46	19.328±0.65		
	Gel base									
NM-1	6.771±0.04	6.668±0.04	6.596±0.03	6.495±0.01	6.639±0.04	6.756±0.05	6.398±0.05	6.282±0.04		
NM-2	6.797±0.04	7.026±0.05	6.921±0.02	6.811±0.05	7.011±0.02	6.908±0.06	6.684±0.04	6.460±0.06		
NM-3	6.661±0.02	6.384±0.04	6.419±0.04	6.139±0.01	6.368±0.06	6.384±0.02	6.199±0.03	6.264±0.03		
NM-4	20.952±0.07	18.008±0.11	19.604±0.38	19.740±0.63	20.152±0.13	19.144±0.29	18.435±0.17	18.469±0.82		
	Nimesulide gel formulation									

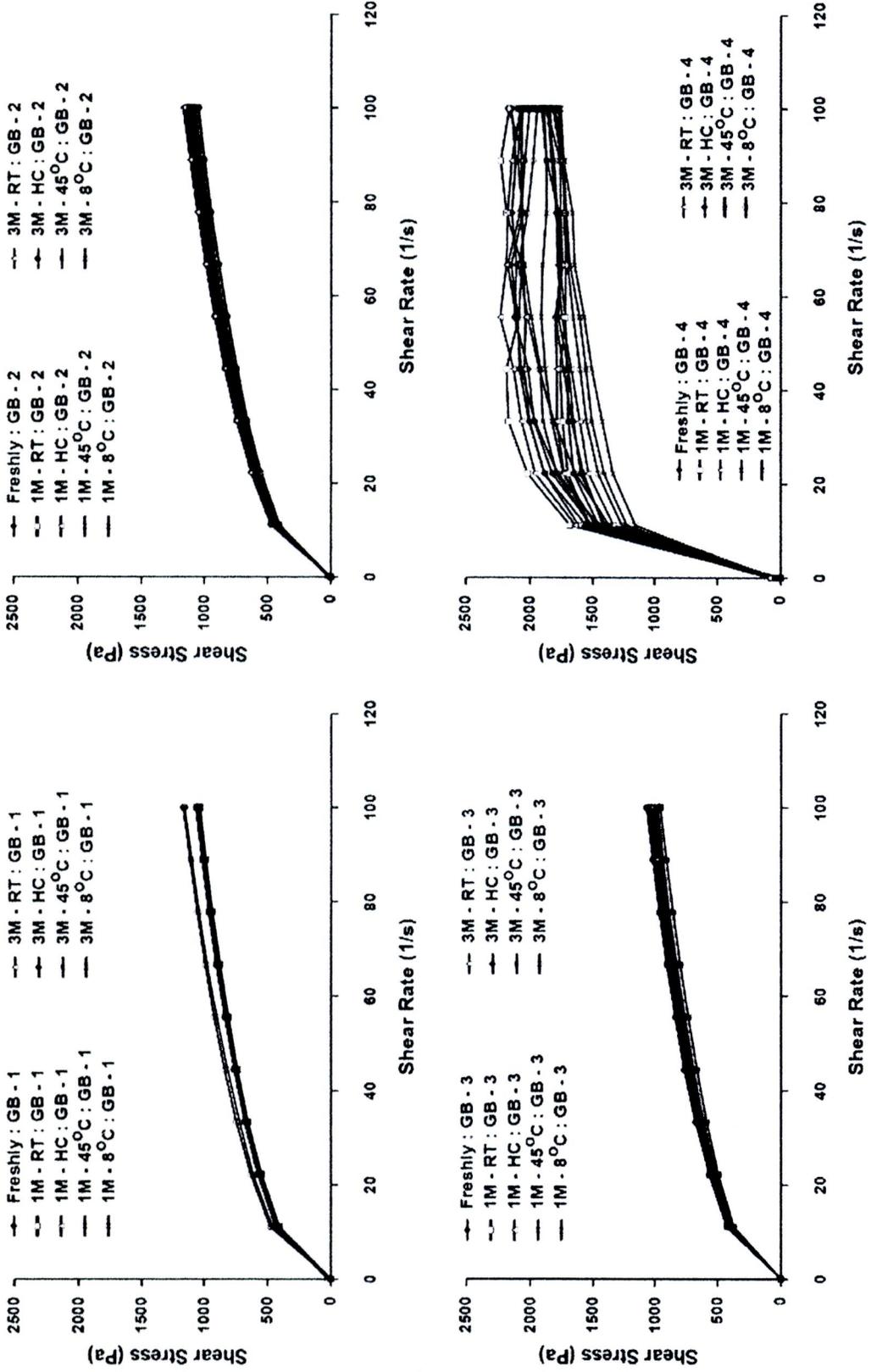


Figure 3.24 The rheograms of gel bases by CL-MB-7, CL-MB-8, CL-MB-9, compared with SCMC in the stability test

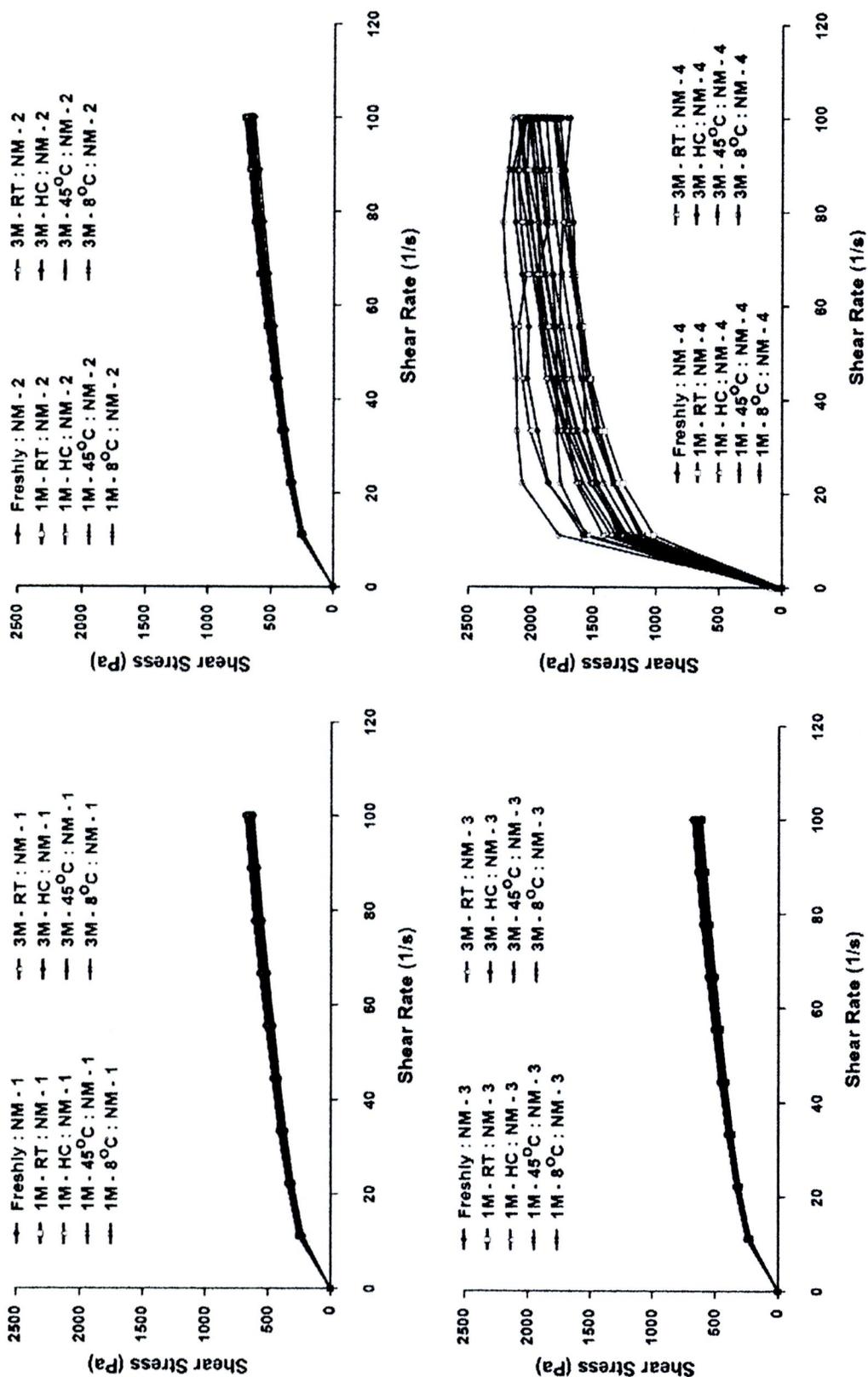


Figure 3.25 The rheograms of NM gel formulations by CL-MB-7, CL-MB-8, CL-MB-9, compared with SCMC in the stability test

The rheograms of gel bases and NM gel formulations, presented in Figure 3.24-3.25, showed a pseudoplastic flow with thixotropy. The viscosity of NM gel formulations were decreased after NM was incorporated into the gel base. The viscosity of gel bases and NM gel formulations were stable at the stability test. After the stability test, the viscosities of NM gel formulations were slightly changed (not significant). The rheological profile of NM-1, NM-2 and NM-3 were significantly less than NM-4 that was prepared from SCMC, but had a gel like appearance. However, the NM gel formulations were stable at all conditions and the best viscosity was shown by NM-2 that used CL-MB-8 as a gelling agent.

3.9 Releasing study of nimesulide gel formulation

The releasing study of NM gel was modified from in-vitro drug diffusion study of Kumar et. al. (2010). The method was determined by using Frantz's diffusion apparatus. The withdrawn sample was detected by UV/VIS spectrophotometer at 392 nm. The amounts of NM released were calculated from NM standard curve, presented in Figure 3.26.

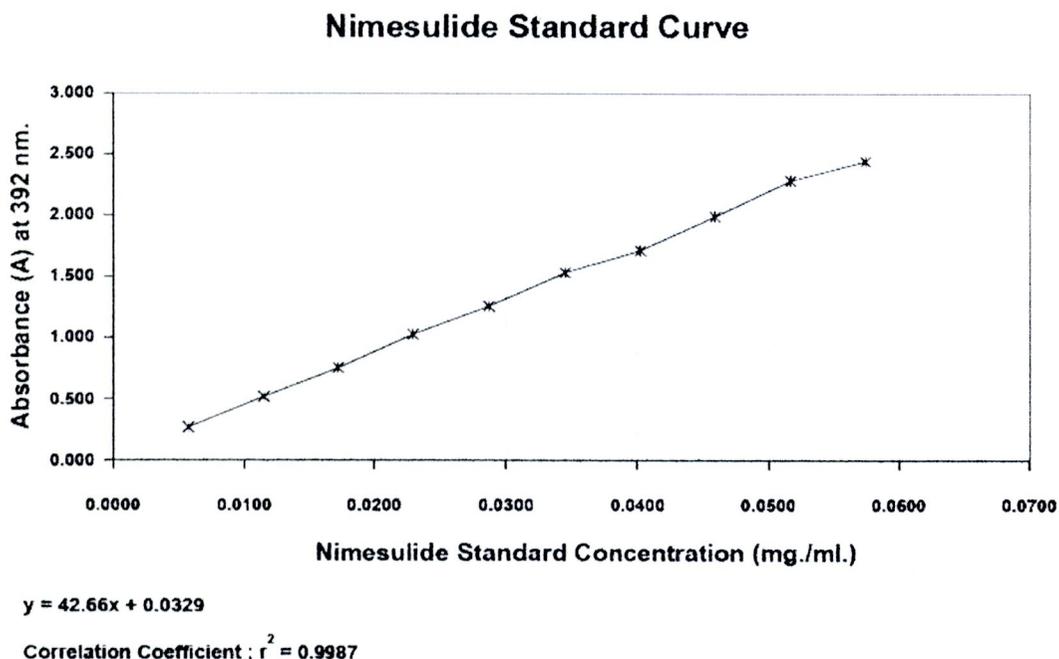


Figure 3.26 Nimesulide standard curve

The released profiles of NM-1, NM-2, NM-3 and NM-4 were shown in Figure 3.27-3.30, respectively.

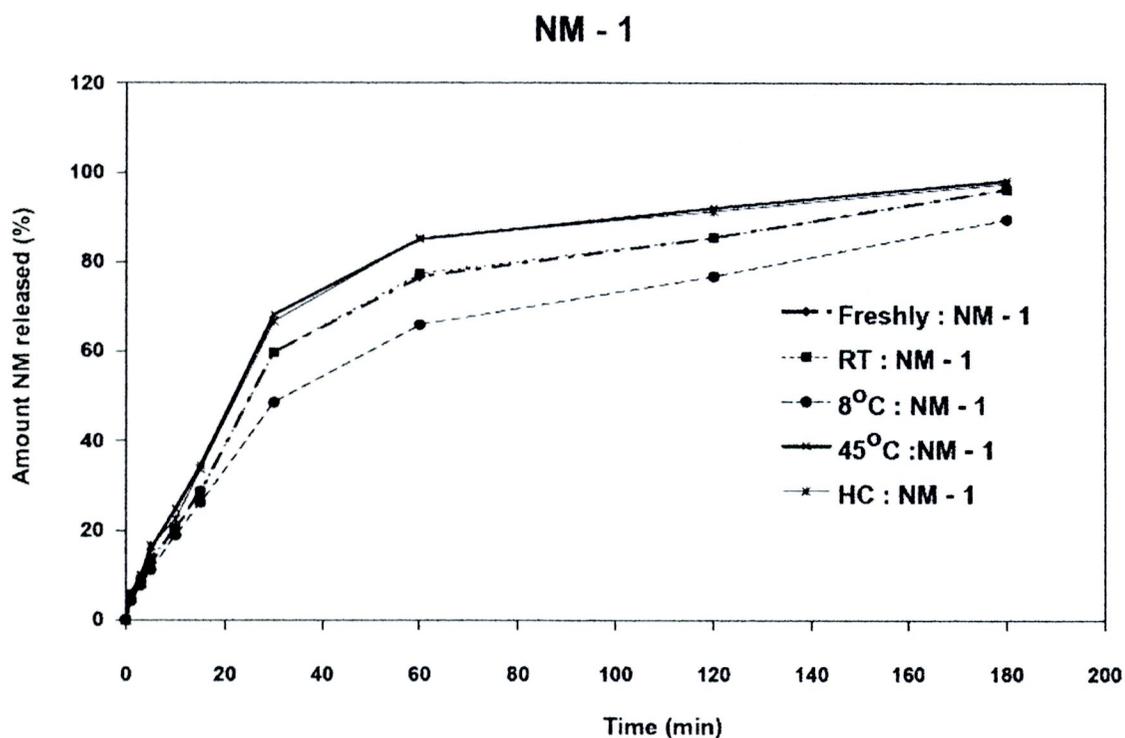


Figure 3.27 Nimesulide released profiles when using CL-MB-7 as a gelling agent

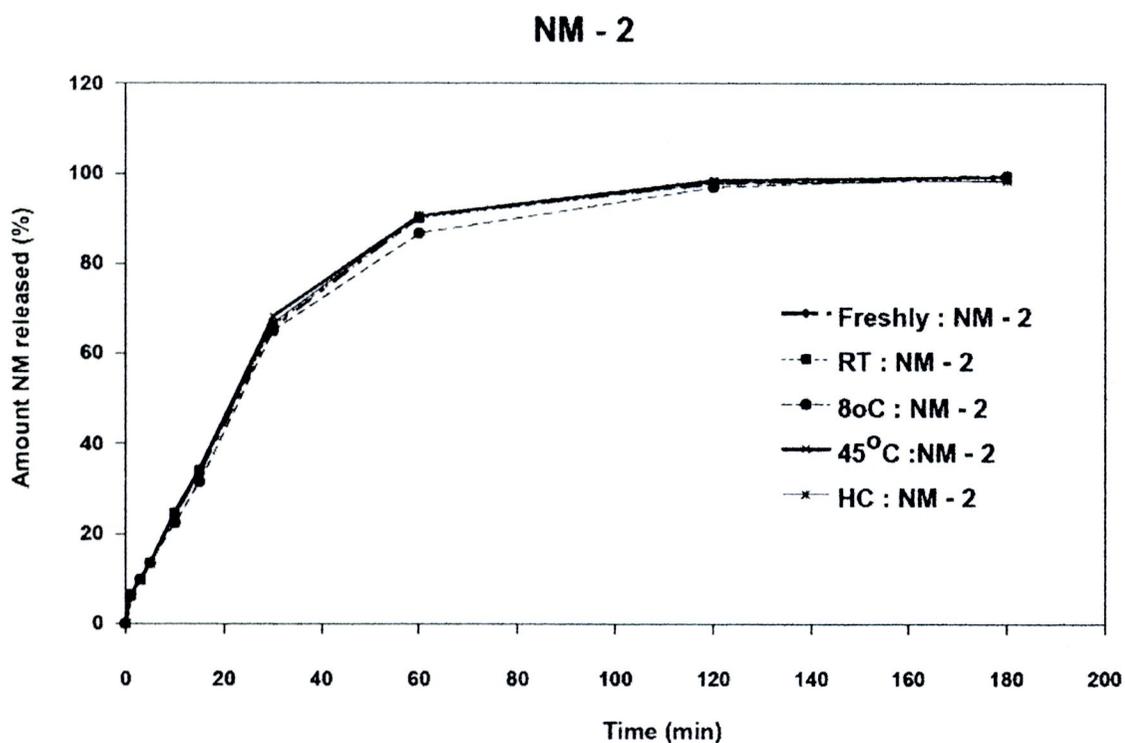


Figure 3.28 Nimesulide released profiles when using CL-MB-8 as a gelling agent

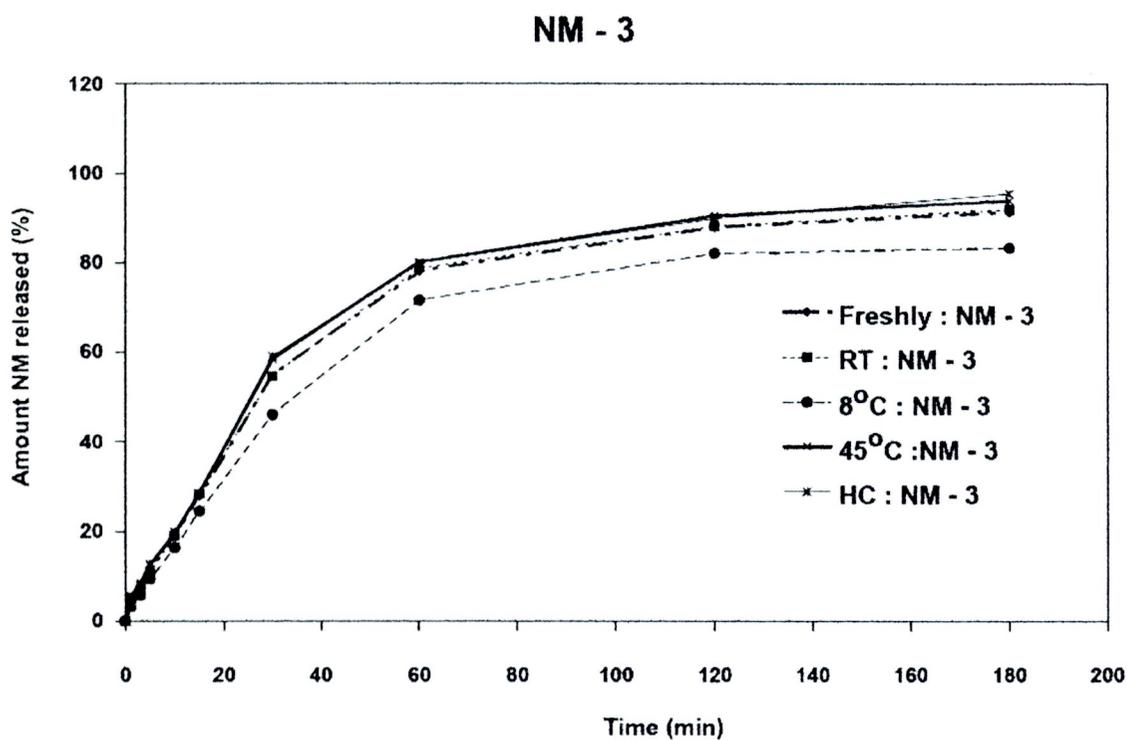


Figure 3.29 Nimesulide released profiles when using CL-MB-9 as a gelling agent

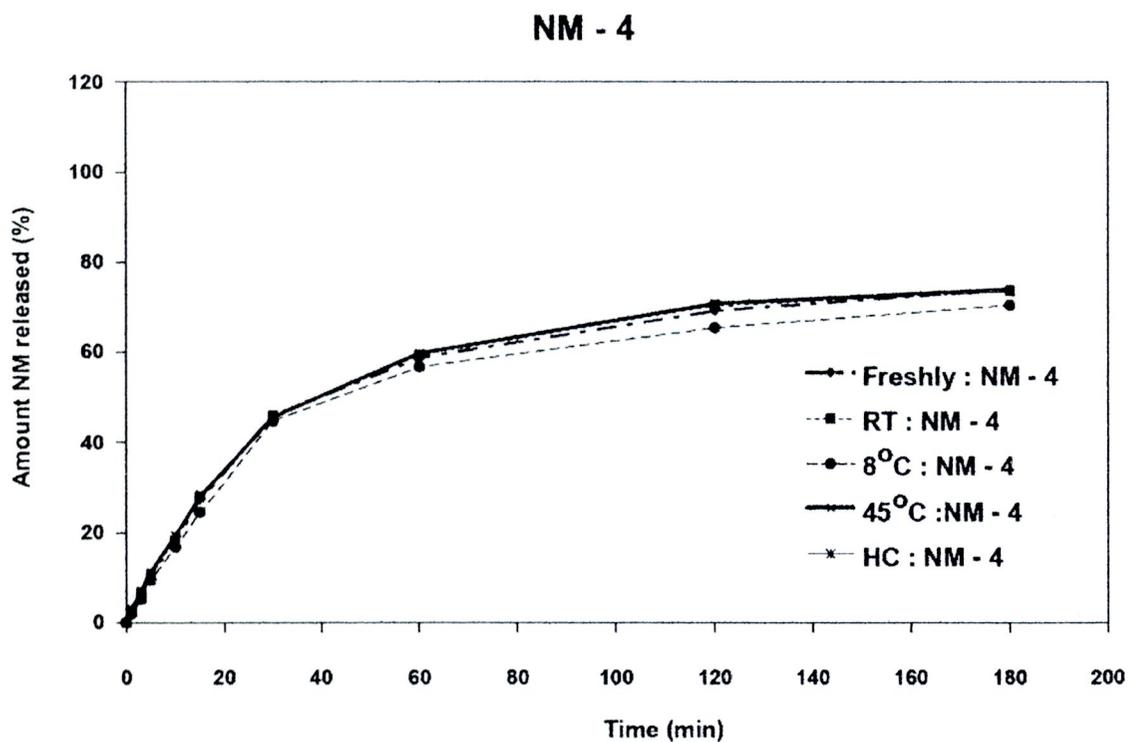


Figure 3.30 Nimesulide released profiles when using SCMC as a gelling agent

The released profiles of NM-1, NM-2, NM-3 and NM-4 were identical with FSC results shown in Figure 3.11. The NM-2 showed complete release after 180 min (Figure 3.28) and the release profile was unchanged after the stability test at 8°C, RT and 45°C, after the HC cycle stability test. Under accelerated conditions, the released profile of NM-3 (Figure 3.29) was only slightly changed but the amount of NM released was less than NM-1 and NM-2. On the other hand, the released profile of NM-1 (Figure 3.27) was significantly changed but the amount of NM released was the same as NM-2. The amount of NM released of NM-4 (Figure 3.30) that was prepared from the commercial polymer SCMC, was lower than NM-1, NM-2 and NM-3 at 180 min. Therefore, the NM-2 exhibited the best NM gel formulation with greater released profile under accelerated conditions, prepared by using CL-MB- 8 as a gelling agent.