CHAPTER III

RESULTS

1. Evaluation of the properties of the modified starches

The modified starches in this study were prepared from five native starches : rice , glutinous rice , corn , tapioca and potato starches, using three different methods of carboxymethylation.

1.1. Determination of degree of substitution

The degree of substitution of various carboxymethyl starches produced by carboxymethylation method 1, 2 and 3 are shown in Table 3 and a calculation method was described in Appendix A. It was seen that carboxymethylation method 1, 2 and 3 produced modified starches in different degree of substitution. Method 1 gave the lowest degree of substitution, followed by method 2 and method 3. The latter method gave the highest.

1.2. Determination of the functional group

The carboxymethyl ($-CH_2COO^-$) groups of the modified starches were easily detected by Infrared Spectrometer (IR). The IR spectra of various native and modified starches are illustrated in Figures 6-10.

Table 3 Degree of substitution of various modified starches produced by three methods.

Type of starch	Code	Substitution method	Degree of substitution
Rice	MRS1	1	0.18
	MRS2	2	0.22
	MRS3	3	0.46
Glutinous rice	MGS1	1	0.19
	MGS2	2	0.35
	MGS3	3	0.49
Corn	MCS1	1	0.20
	MCS2	2	0.38
	MCS3	3	0.45
Tapioca	MTS1	1	0.24
	MTS2	2	0.36
	MTS3	3	0.39
Potato	MPS1	1	0.22
	MPS2	2	0.37
	MPS3	3	0.44

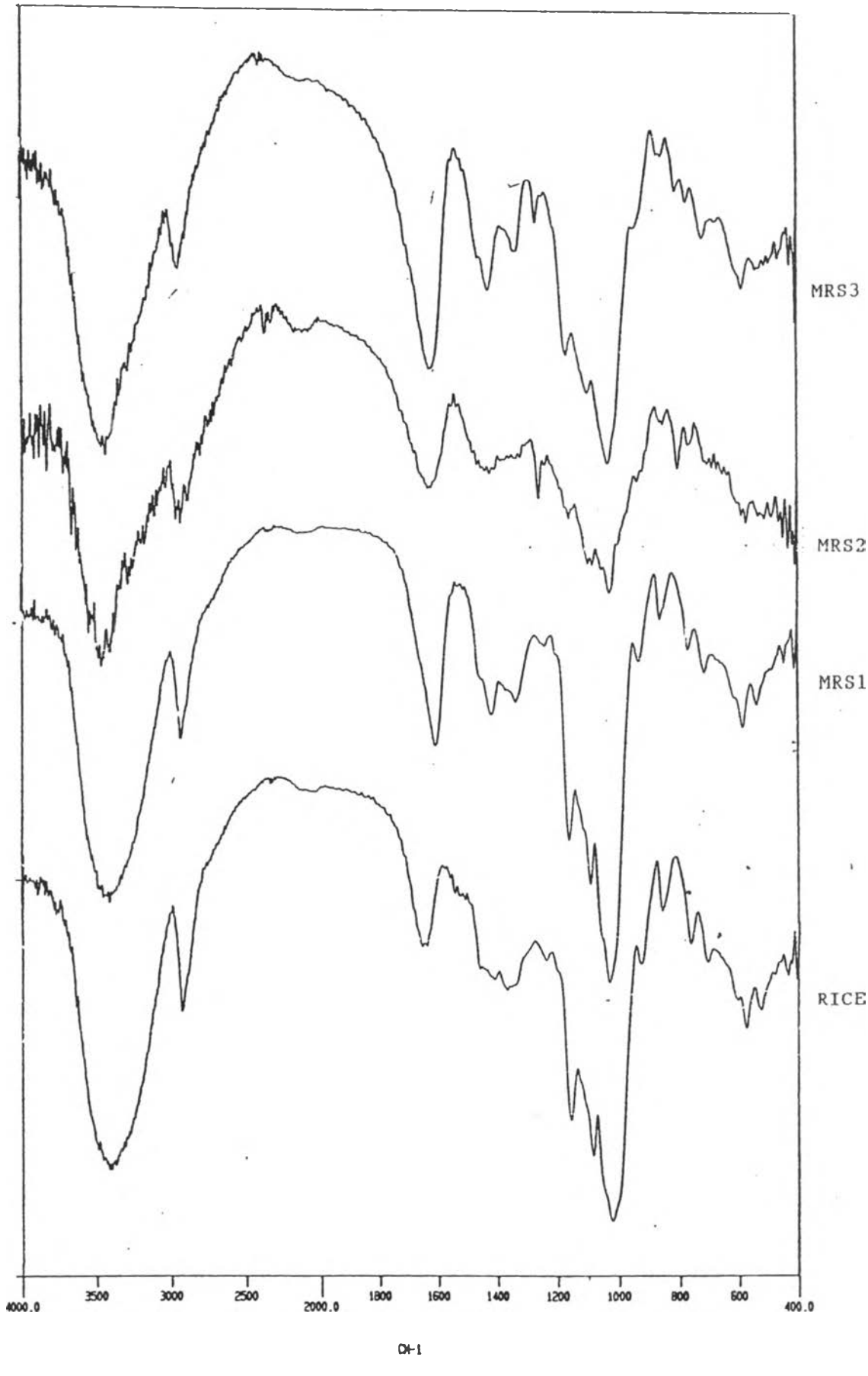

Figure **6** Infrared Spectra of Native and Modified Rice Starches.

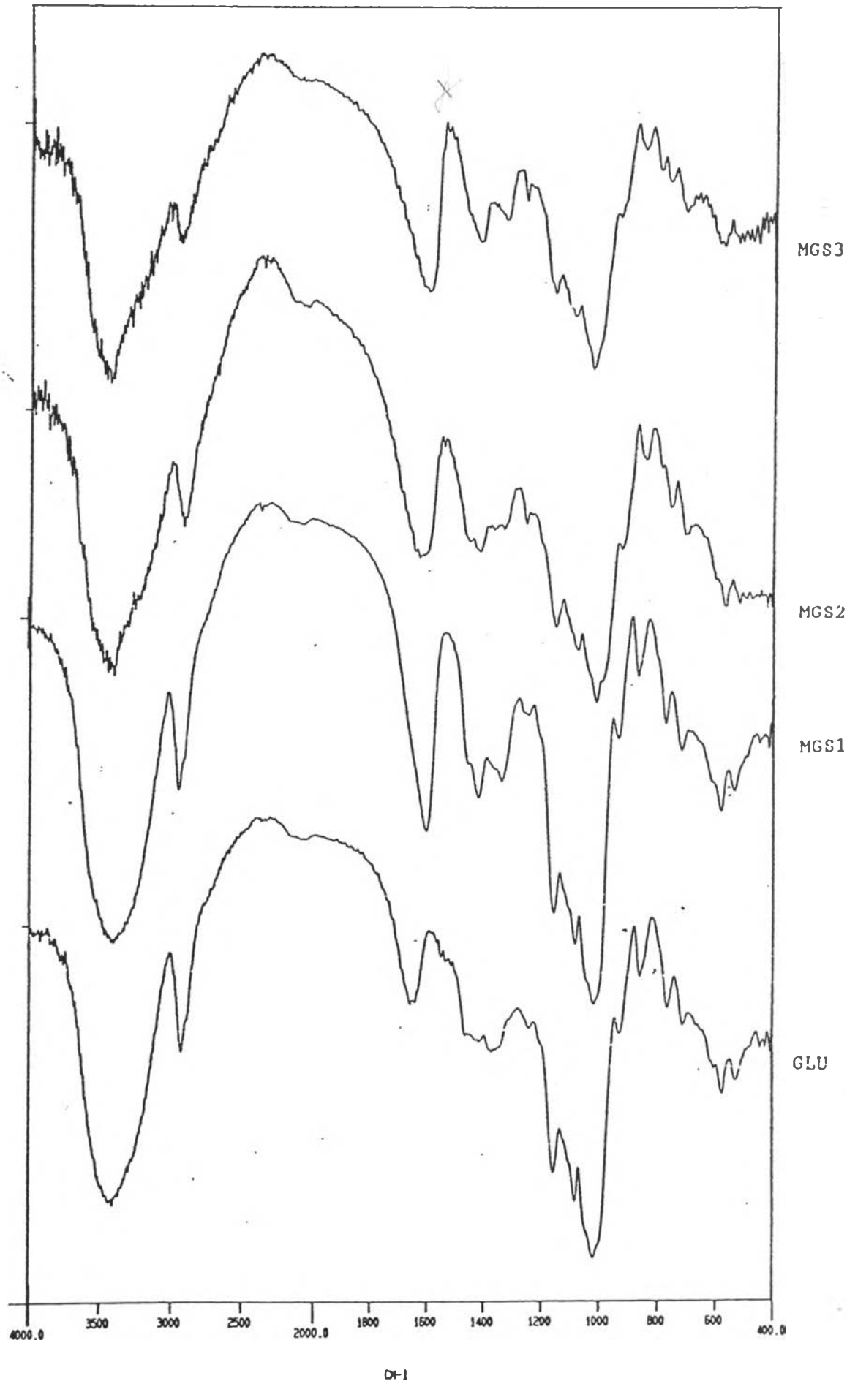

Figure 7 Infrared Spectra of Native and Modified Glutinous Rice Starches.

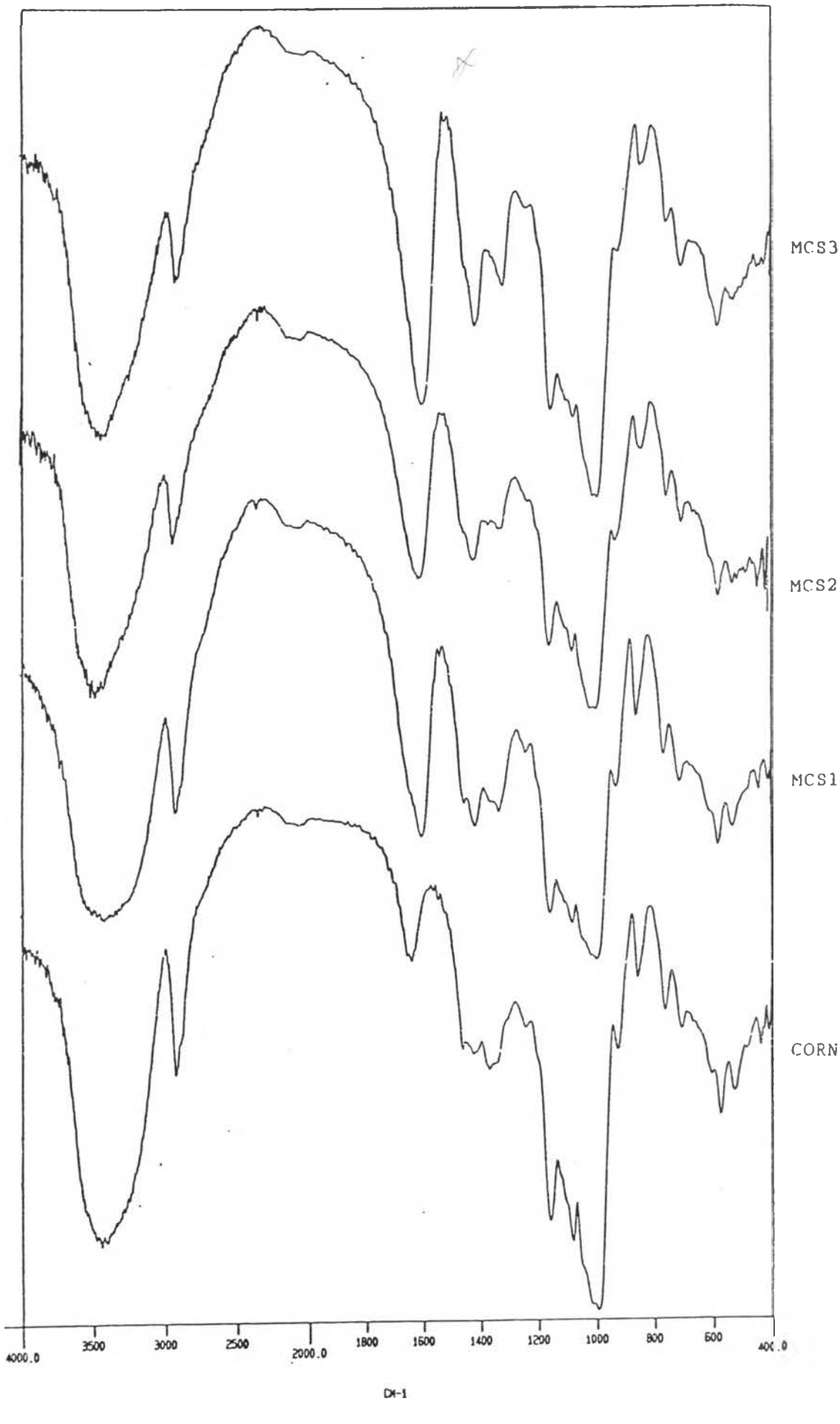

Figure **8** Infrared Spectra of Native and Modified Corn Starches.

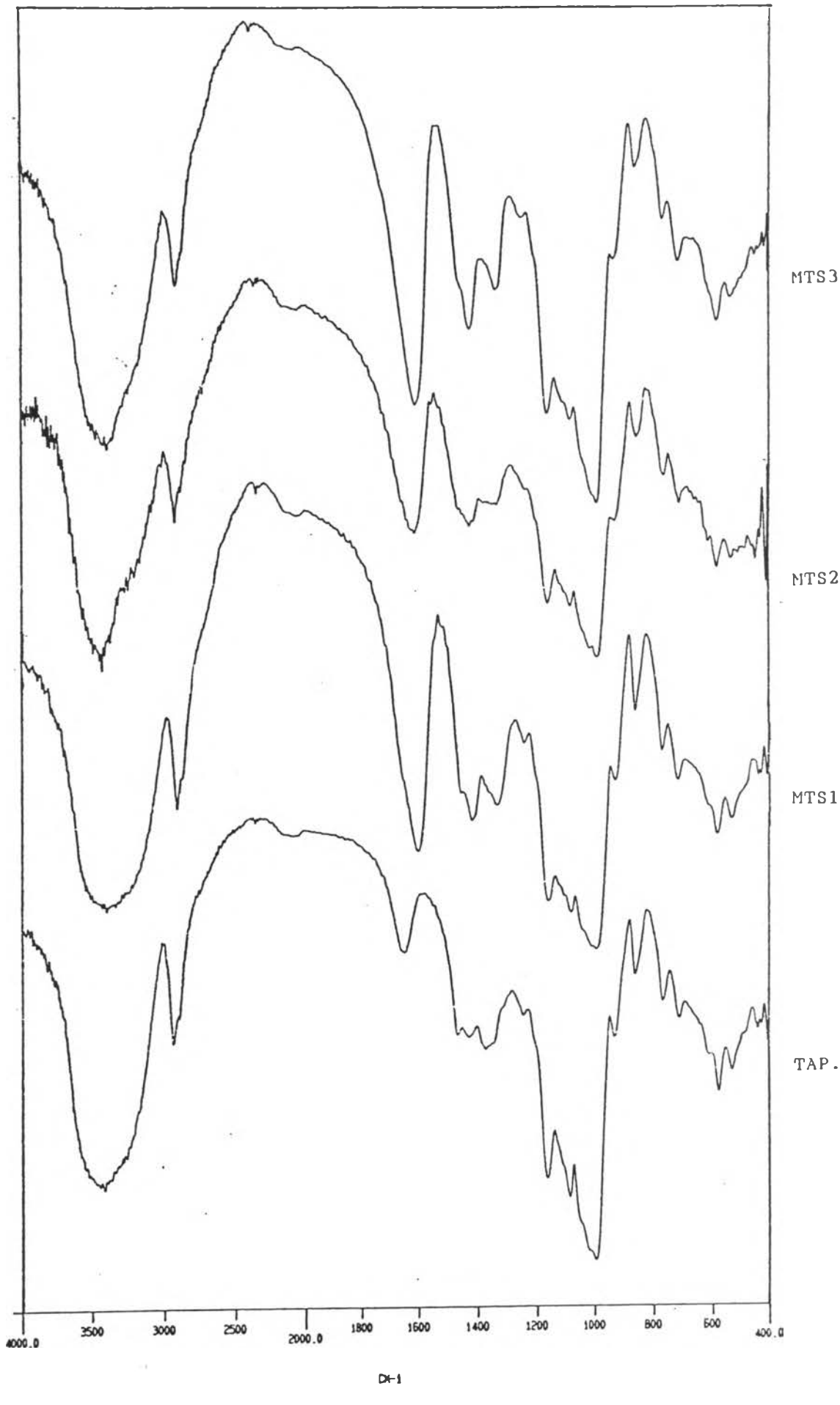

Figure 9 Infrared Spectra of Native and Modified Tapioca Starches.

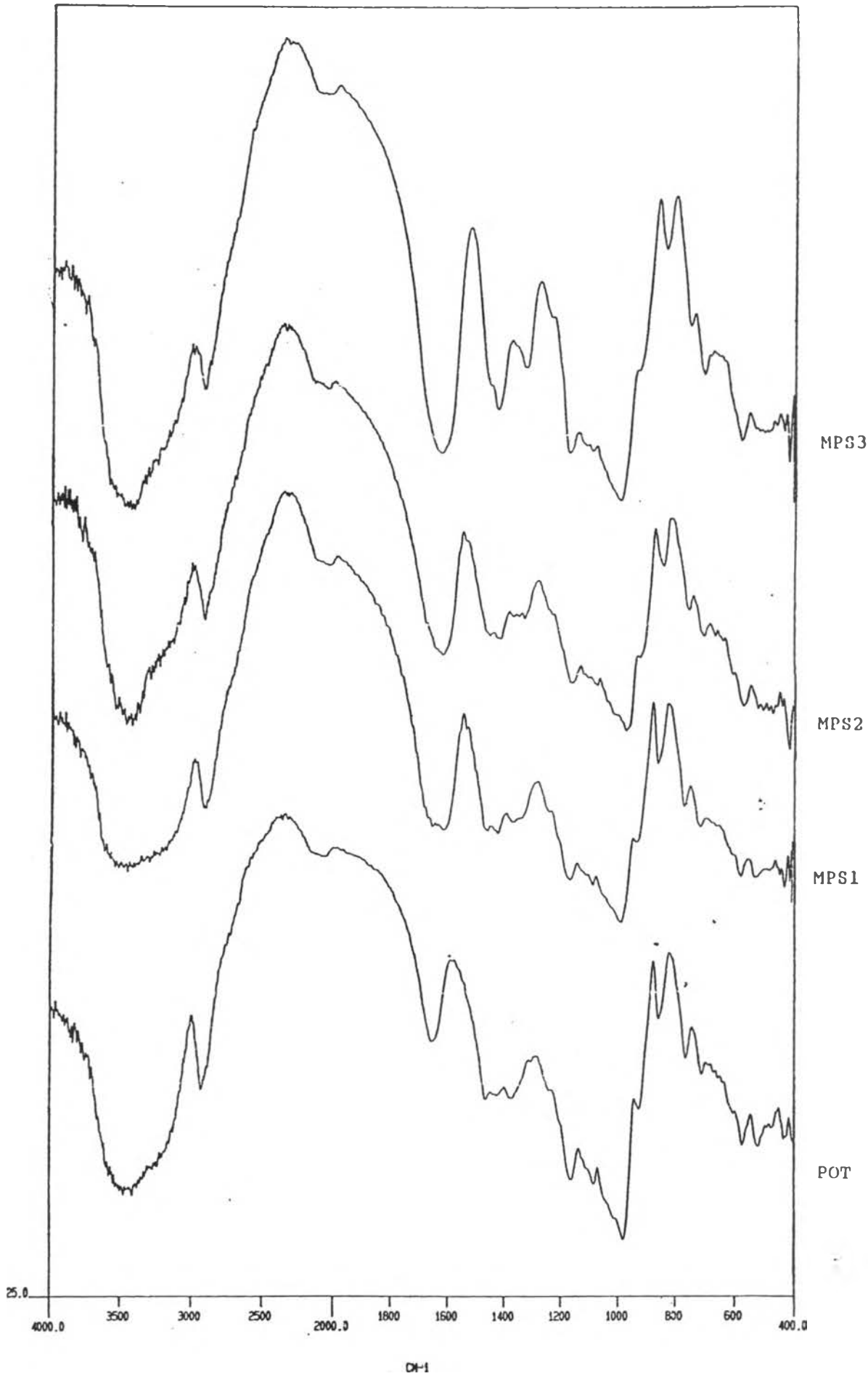

Figure **10** Infrared Spectra of Native and Modified Potato Starches.

The spectra of various native and modified starches had the same four important zones. The first was a strong broad OH-stretching band centering near 3400 cm^{-1} . The second was a CH-stretching band near 2900 cm^{-1} . The third was in a 1160-1100 cm^{-1} region involving C-O stretching of COH and COC groups. The last was in the 960-730 cm^{-1} region. This zone was used to characterize carbohydrate types. For starch, an alpha-D-glucose polymer, had band at 844±8 cm^{-1} . However, it could be seen that the modified starch spectra were different from those of their native. The modified starch spectra had an intense band near 1600 cm^{-1} which indicated that it was CO stretching of carboxyl salt. The C=O and C-O of the carboxyl salt were replaced by two equivalent C=O bonds which were intermediate in force constant between the C=O and C-O (Colthup, Daly and Wiberley, 1975).

1.3. Moisture determination

The percent moisture content is depicted in Table 4. It was observed that the moisture content of various native and modified starches revealed no difference, except potato starch. An average value of the percent moisture content was mostly ranging from 9.60-13.75 %. Era-Pac^{R} and Era-Gel^{R} as reference binders in this study also had percent moisture in this range.

1.4. Viscosity measurement

The Brabender Visco-Amylograph with cartridge 700 cmg. was used to measure the viscosity of native and modified starches and the

Table 4 Percent moisture content of native and modified starches.

Type of starches	% Moisture content
Rice	11.56
MRS1	12.11
MRS2	12.11
MRS3	12.11
Glutinous rice	13.00
MGS1	10.67
MGS2	11.56
MGS3	11.00
Corn	13.67
MCS1	11.31
MCS2	12.48
MCS3	13.05
Tapioca	13.00
MTS1	9.60
MTS2	12.67
MTS3	12.00
Potato	16.00
MPS1	11.00
MPS2	13.75
MPS3	13.11
Era-Pac^{R}	11.89
Era-Gel^{R}	10.56

Brabender viscosity curves are displayed in Figures 11 to 16. In this measurement, the concentration of a starch suspension was 5% w/w, except of glutinous rice starch and potato starch was 2% w/w, as the viscosity of these two starches at some degrees of substitution exceeded the measuring range of the 700 cmg cartridge. In order to avoid damage to the sensor shaft, the concentration of these two starches might be decreased. From the Figures, it was seen that the viscosity curves of various native starches were different. For unmodified rice, tapioca and potato starches, an increase of viscosity was not seen as the starch suspension was initially heated, until the gelatinization temperature was reached, the viscosity increased rapidly. After that, the viscosity remained constant through the holding period. During cooling period, the viscosity of rice starch further increased whereas the viscosity of tapioca and potato was unchanged. The Brabender curves of glutinous rice starch and corn starch showed relative low and consistent viscosity throughout the cooking, holding and cooling cycles. Although the patterns of the viscosity curve of various native starches were different, those of the modified starches were similar. It could be observed that, at 30 - 60 °C, most of the modified starches were more viscous than their native starches. The viscosity curves of all types and degrees of substitution of the modified starches decreased during the cooking cycle. After the cooking period, the viscosity of the modified starches tended to be constant. The viscosity of various modified rice and glutinous rice starches was ranging as followed : MRS1 ~ MGS1 > MRS3 ~ MGS3 > MRS2 ~ MGS2. The viscosity of modified corn starch produced by method 1, 2 or 3 were comparable. For modified tapioca and potato starches, method 2 produced products with the highest viscosity, then

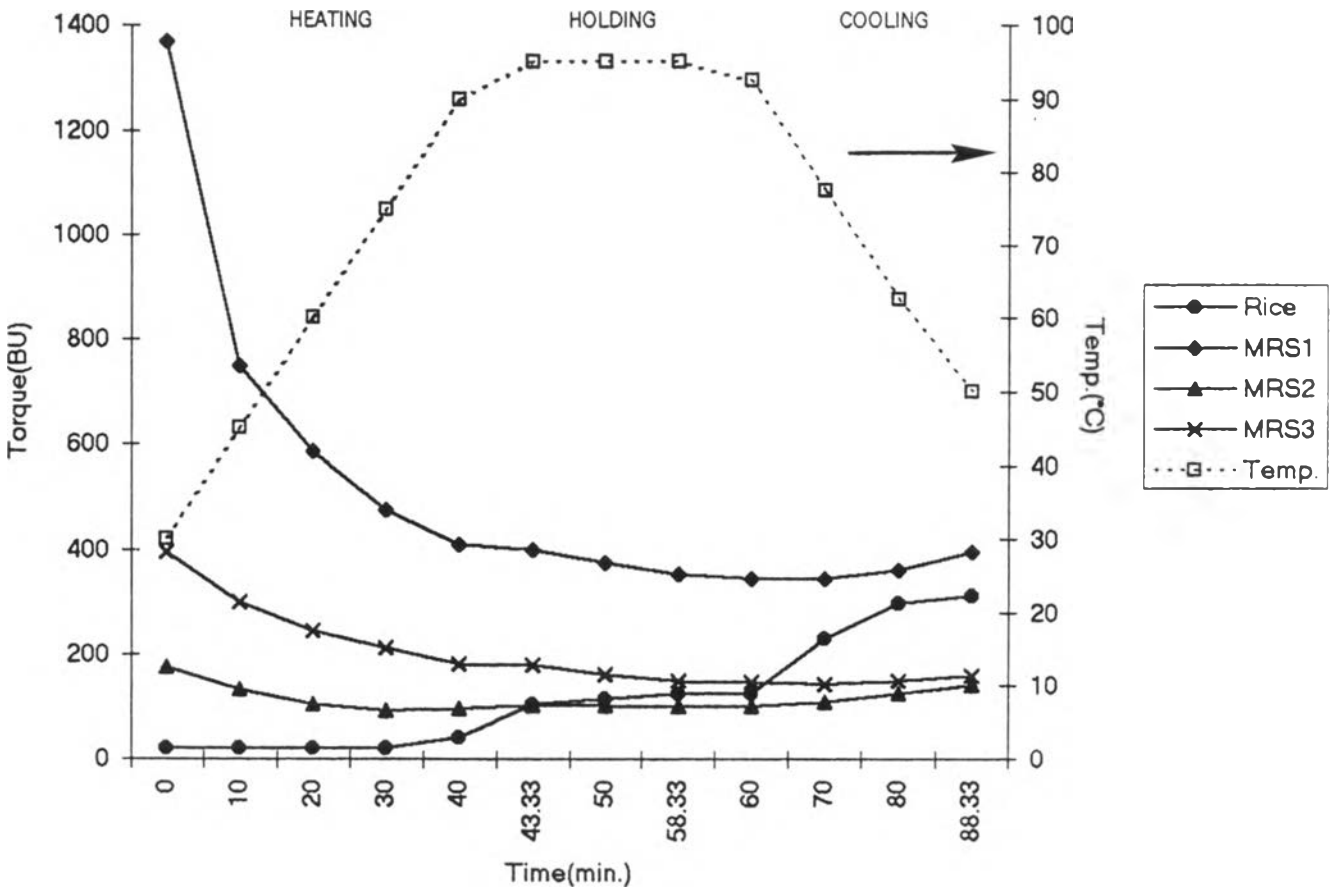

Figure 11 Brabender viscosity curves of rice, MRS1, MRS2 and MRS3. The concentration was 5% w/w of dry starch suspended in distilled water. The starch suspension was heated from 30 °C to 95 °C at a rate of 1.5 °C/min. It was then maintained at 95 °C for 15 min. and then cooled to 50 °C at the same rate.

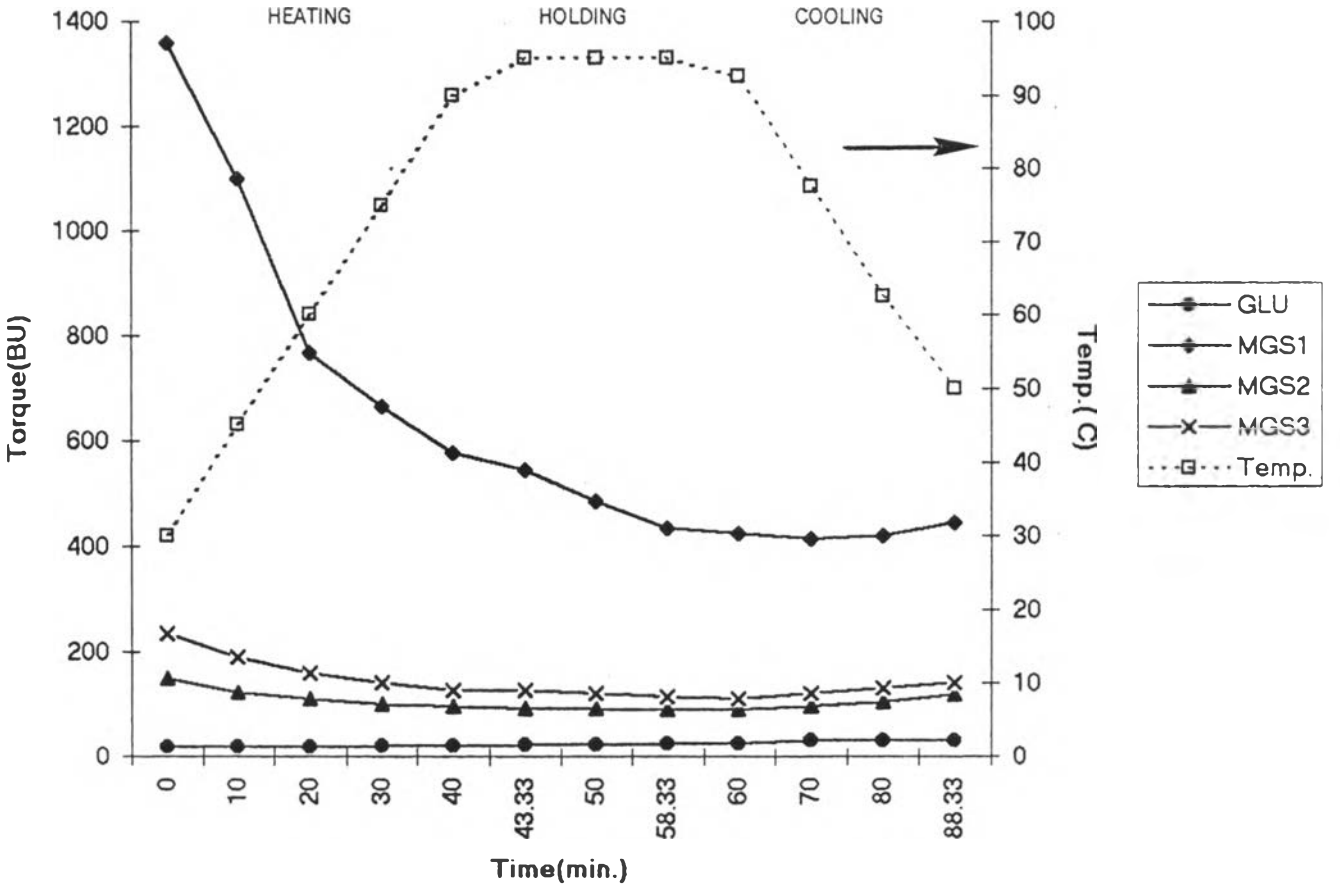

Figure 12 Brabender viscosity curves of glutinous rice, MGS1, MGS2 and MGS3. The concentration was 2% w/w of dry starch suspended in distilled water. The starch suspension was heated from 30 °C to 95 °C at a rate of 1.5 °C/min. It was then maintained at 95 °C for 15 min. and then cooled to 50 °C at the same rate.

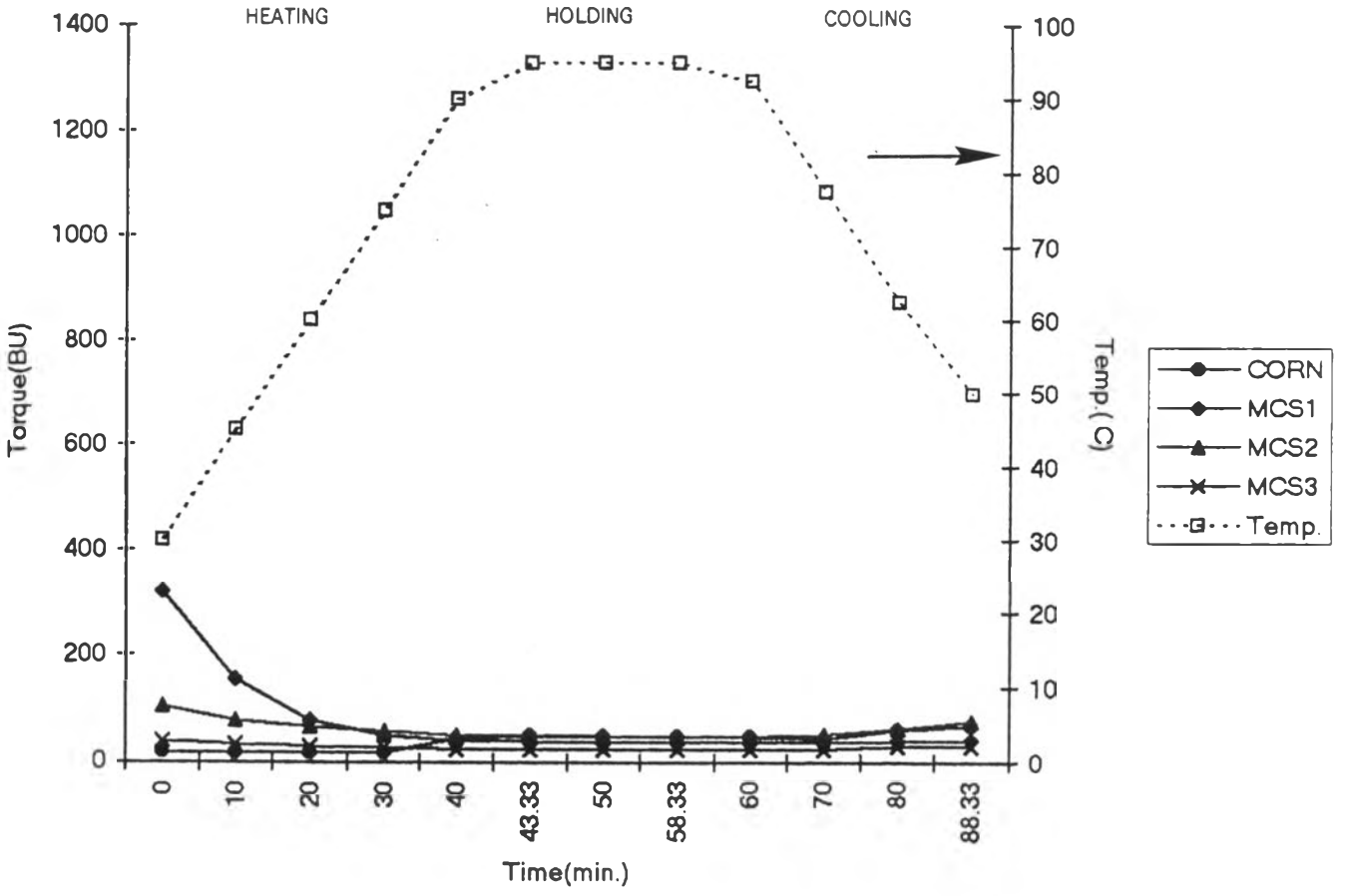

Figure 13 Brabender viscosity curves of corn, MCS1, MCS2 and MCS3. The concentration was 5% w/w of dry starch suspended in distilled water. The starch suspension was heated from 30 °C to 95 °C at a rate of 1.5 °C/min. It was then maintained at 95 °C for 15 min. and then cooled to 50 °C at the same rate.

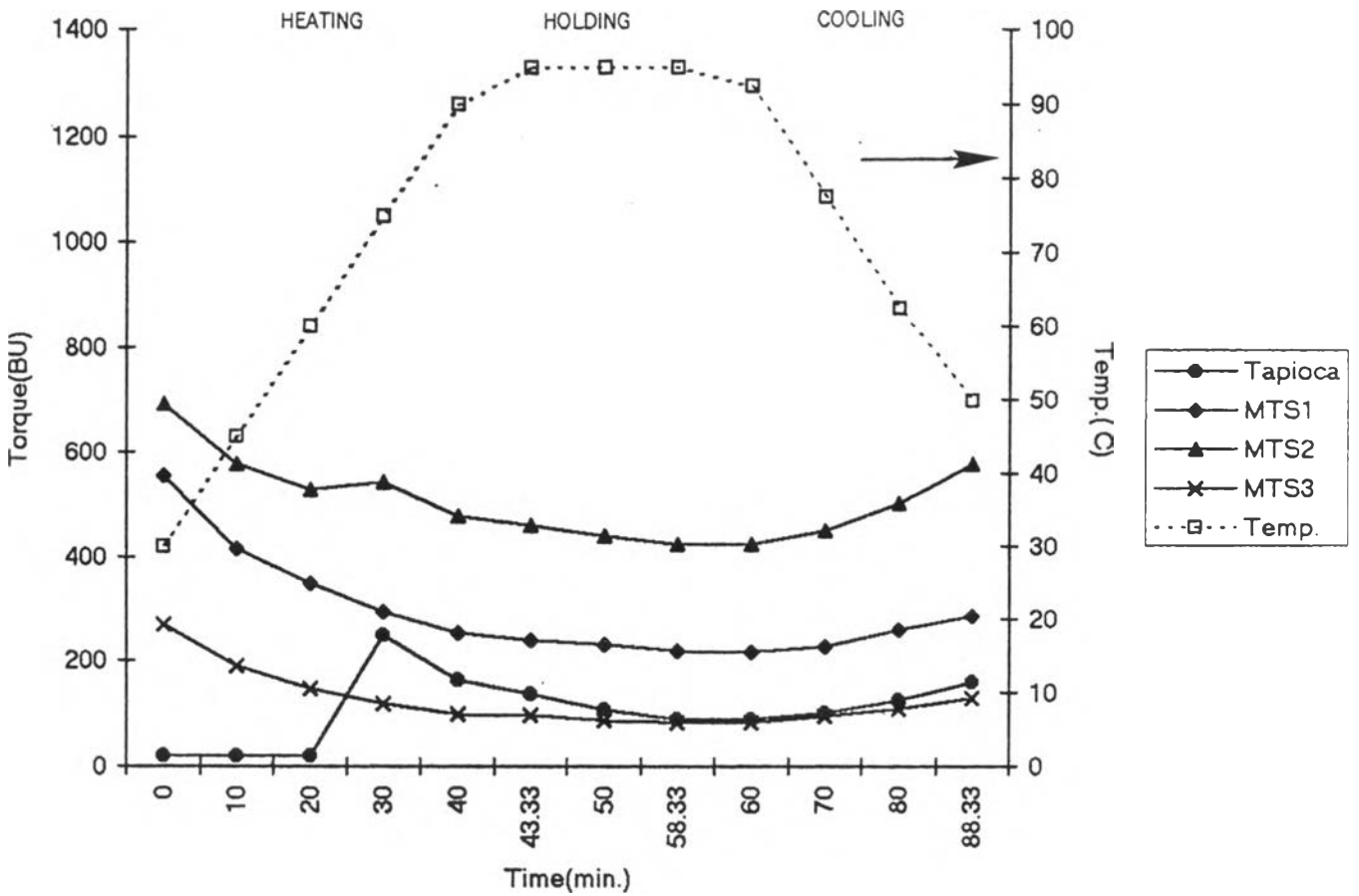

Figure 14 Brabender viscosity curves of tapioca, MTS1, MTS2 and MTS3. The concentration was 5% w/w of dry starch suspended in distilled water. The starch suspension was heated from 30 °C to 95 °C at a rate of 1.5 °C/min. It was then maintained at 95 °C for 15 min. and then cooled to 50 °C at the same rate.

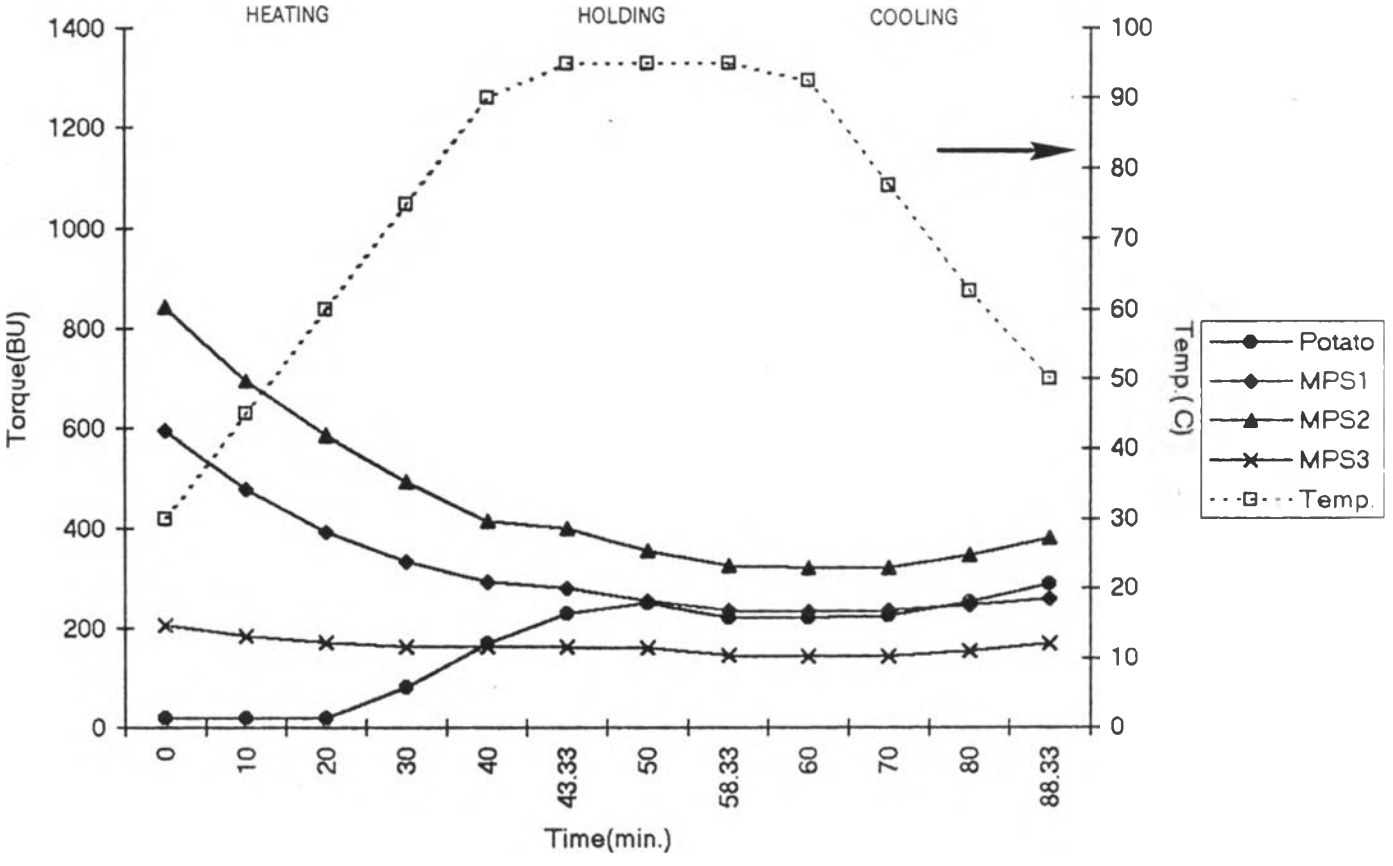

Figure 15 Brabender viscosity curves of potato, MPS1, MPS2 and MPS3. The concentration was 2% w/w of dry starch suspended in distilled water. The starch suspension was heated from 30 °C to 95 °C at a rate of 1.5 °C/min. It was then maintained at 95 °C for 15 min. and then cooled to 50 °C at the same rate.

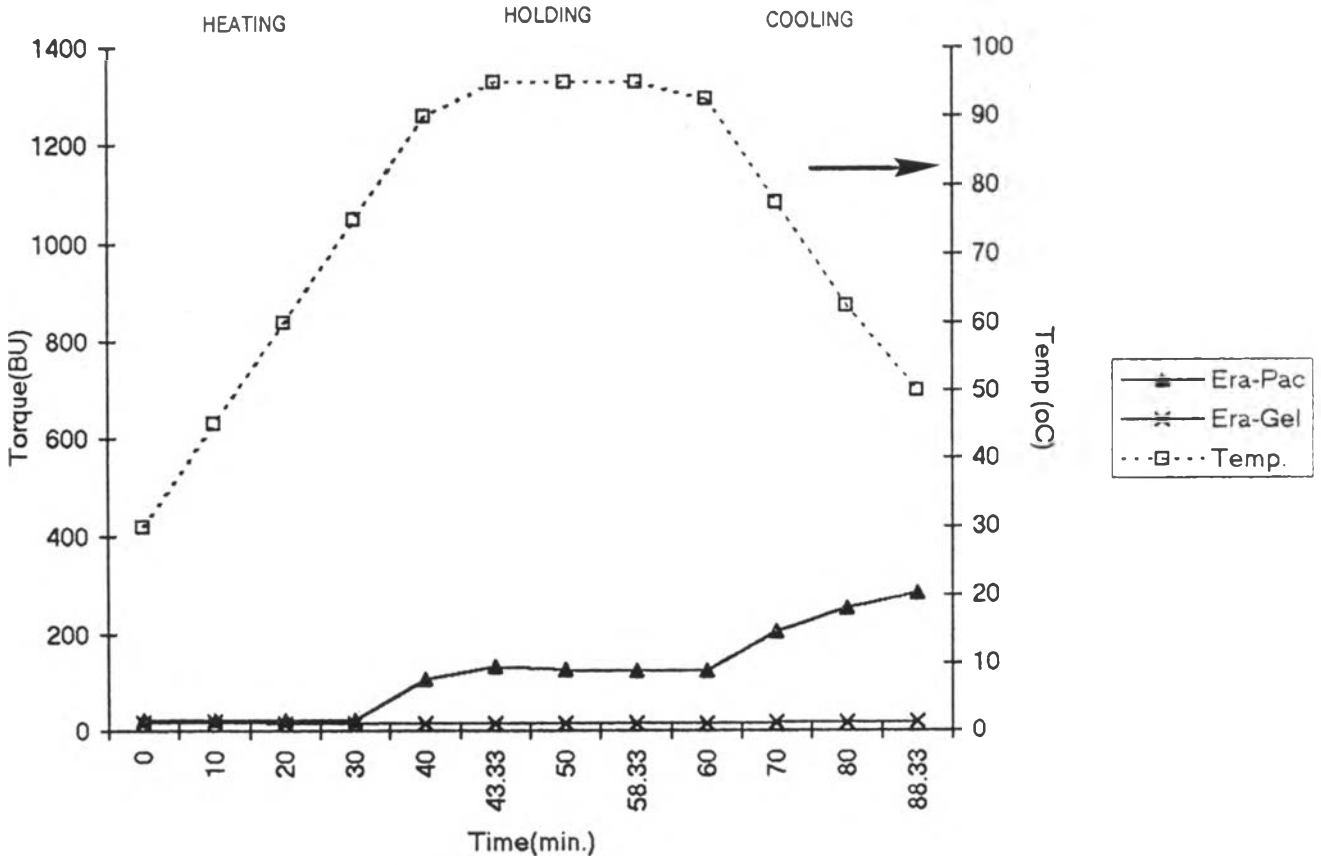

Figure 16 Brabender viscosity curves of Era-Pac^{R} and Era-Gel^{R}. The concentration was 5% w/w of dry starch suspended in distilled water. The starch suspension was heated from 30 °C to 95 °C at a rate of 1.5 °C/min. It was then maintained at 95 °C for 15 min. and then cooled to 50 °C at the same rate.

method 1 and then method 3. To be used as comparative modified starches, Era-Pac^R and Era-Gel^R were also observed for their viscosity. It was seen that the viscosity of Era-Pac^R was higher than of Era-Gel^R and its pattern was the same as the pattern of native rice starch.

2. Evaluation of granule and tablet properties

2.1. Evaluation of the physical properties of paracetamol granules and tablets containing various types, degrees of substitution and percentages of the modified starches were as followed.

2.1.1. Particle size distribution

The particle size of paracetamol granules was examined by sieve analysis method and the results are depicted in Figures 17-46 and Tables 17-22 (in Appendix C). In order to determine geometric mean diameter (D_{50}) , the cumulative percentage undersize was plotted against sieve size on log-probability scale and the plots are illustrated in Figures 97-102 (see appendix C). D_{50} of paracetamol granules using various native or modified starches at 1, 1.5 and 2% dry weight are shown in Figures 47-56. By solution incorporation method, the size distribution of the granules using the modified starches was narrow in comparison to those containing the native starches. This could be obviously seen when the binder was used at 2% dry weight in a formular. D_{50} of the granules using the modified starches was larger than of others containing the native starches. As a dry form, the modified starches yielded the granules with slightly narrower distribution and slightly greater D_{50} in comparison to which as a paste form.

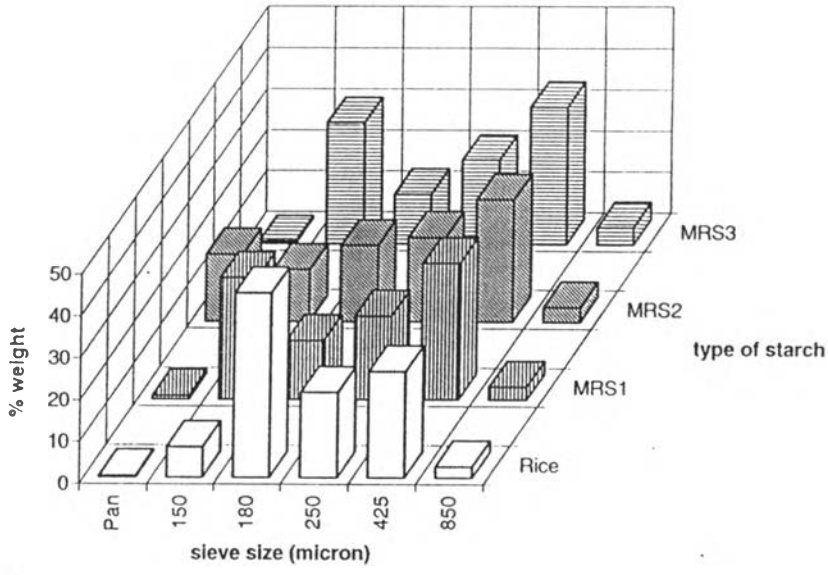

Figure 17 Histograms for particle size distribution of paracetamol granules prepared with rice, MRS1, MRS2 and MRS3 at 1% dry weight by solution incorporation method

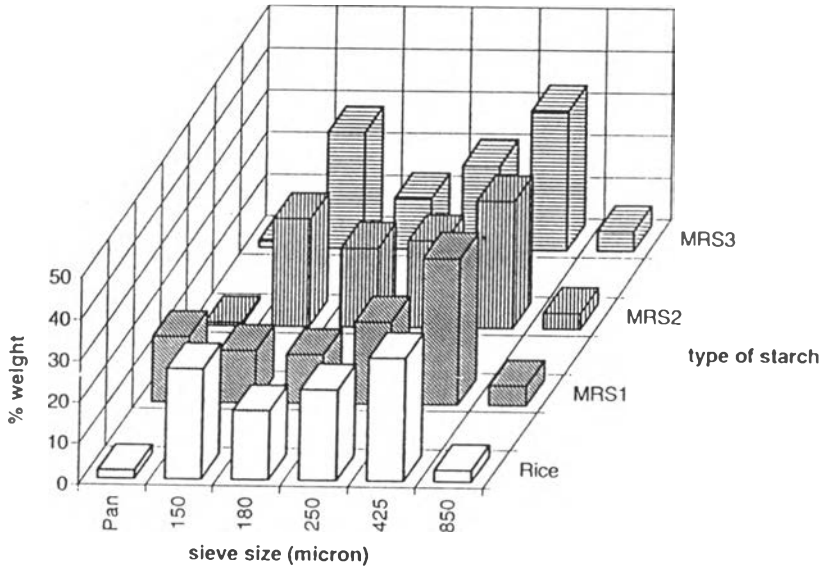

Figure18 Histograms for particle size distribution of paracetamol granules prepared with rice, MRS1, MRS2 and MRS3 at 1.5% dry weight by solution incorporation method

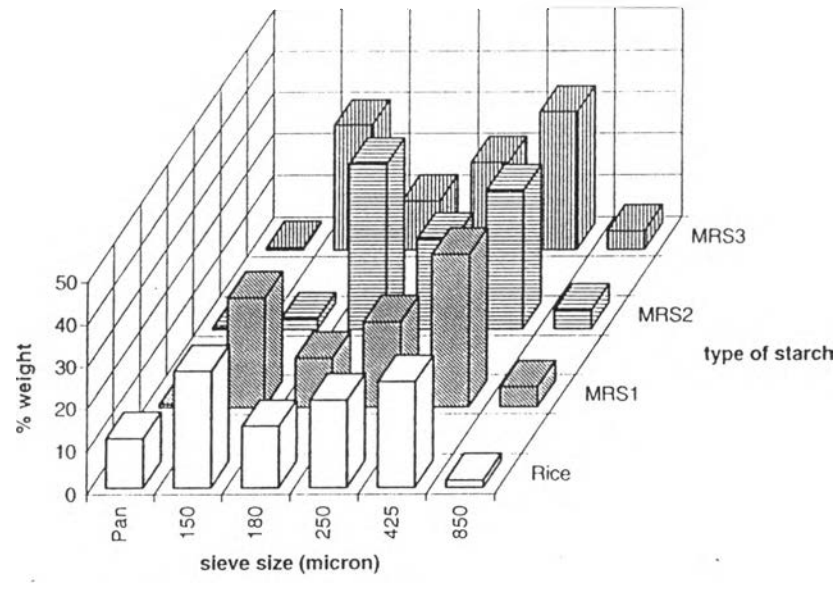

Figure **19** Histograms for particle size distribution of paracetamol granules prepared with rice, MRS1, MRS2 and MRS3 at 2% dry weight by solution incorporation method

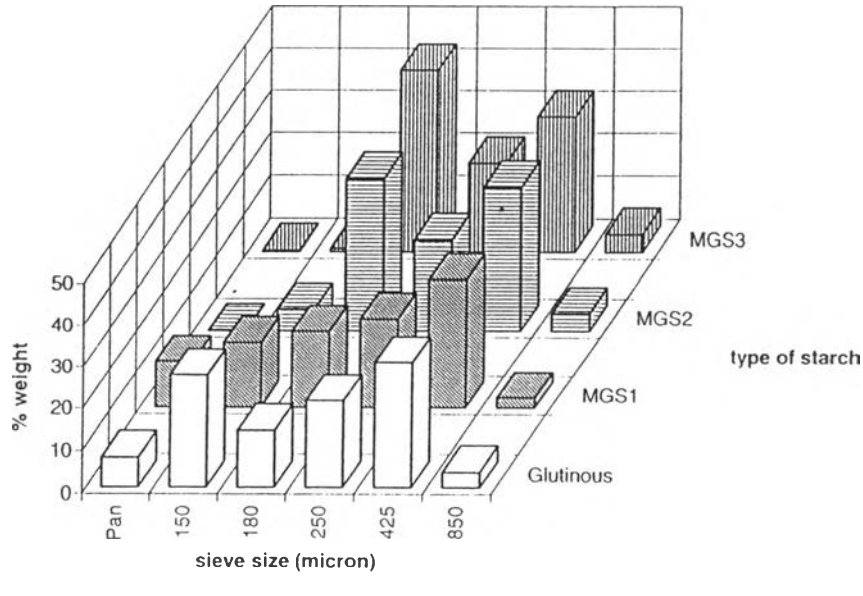

Figure **20** Histograms for particle size distribution of paracetamol granules prepared with glutinous rice, MGS1, MGS2 and MGS3 at 1% dry weight by solution incorporation method

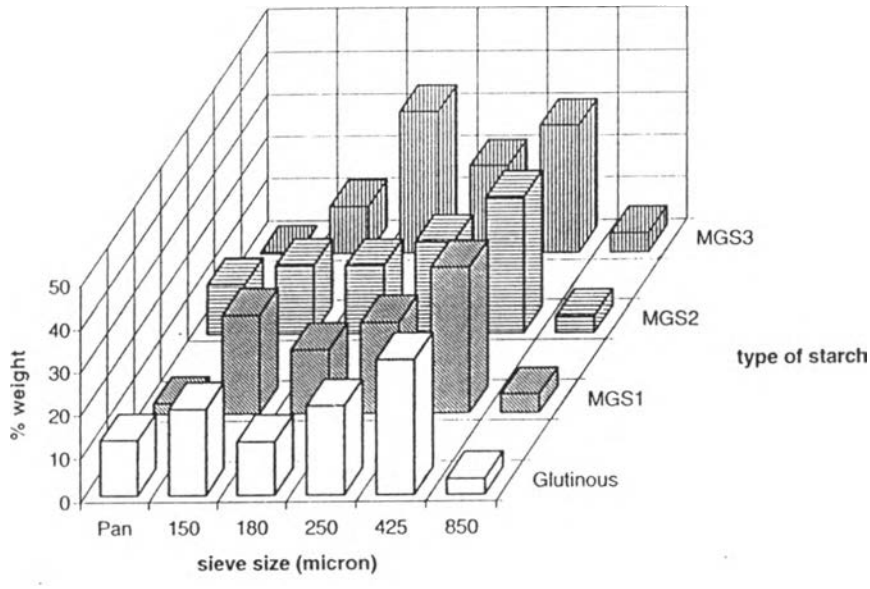

Figure **21** Histograms for particle size distribution of paracetamol granules prepared with glutinous rice, MGS1, MGS2 and MGS3 at 1.5% dry weight by solution incorporation method

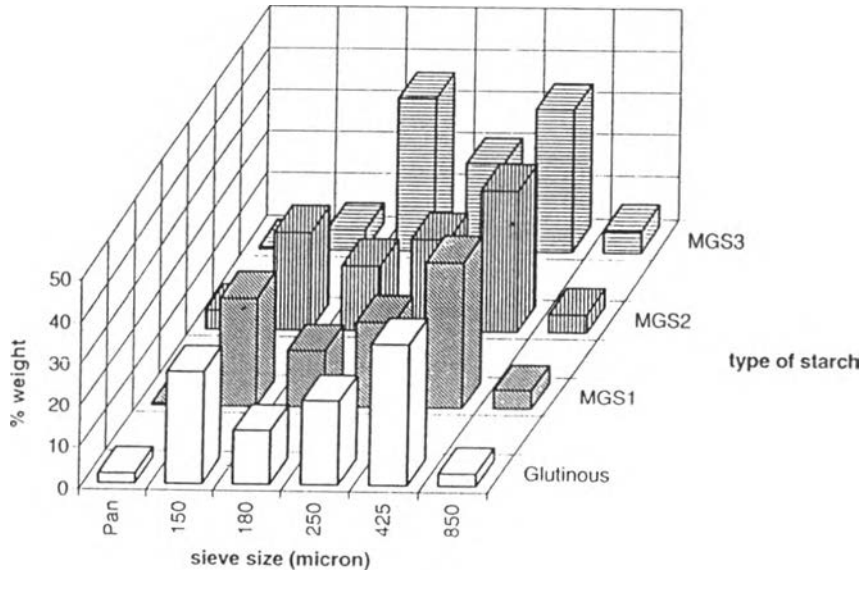

Figure **22** Histograms for particle size distribution of paracetamol granules prepared with glutinous rice, MGS1, MGS2 and MGS3 at 2% dry weight by solution incorporation method

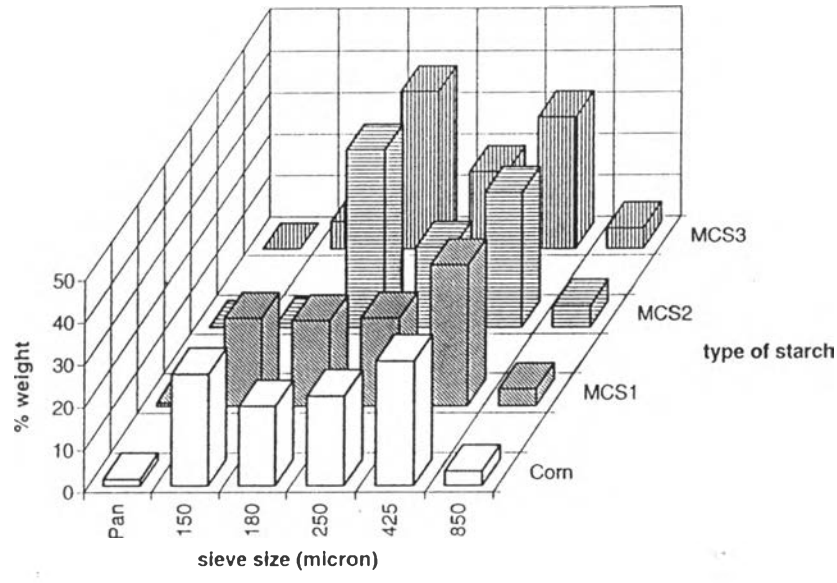

Figure **23** Histograms for particle size distribution of paracetamol granules prepared with corn, MCS1, MCS2 and MCS3 at 1% dry weight by solution incorporation method

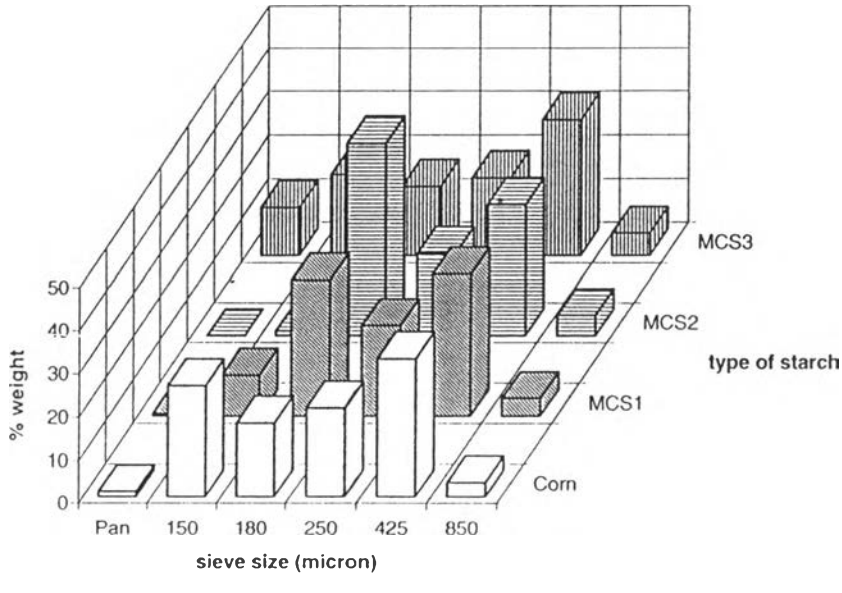

Figure **24** Histograms for particle size distribution of paracetamol granules prepared with corn, MCS1, MCS2 and MCS3 at 1.5% dry weight by solution incorporation method

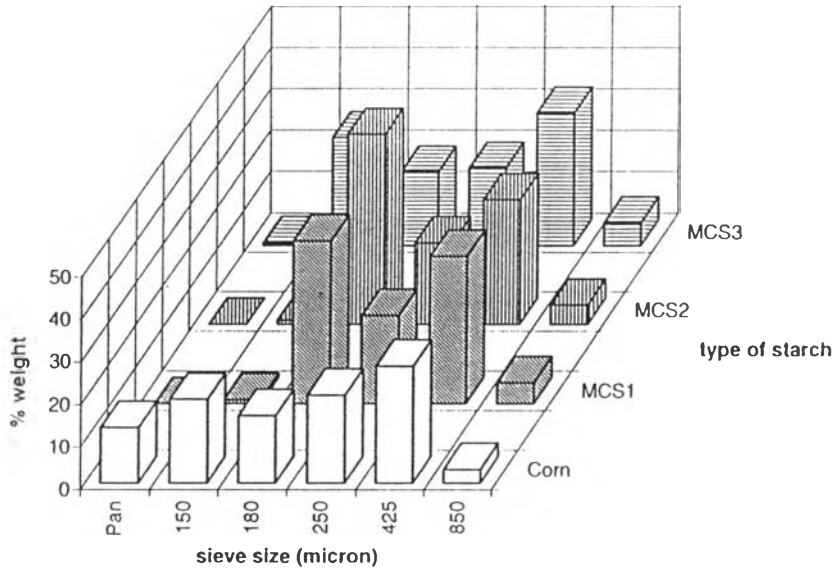

Figure **25** Histograms for particle size distribution of paracetamol granules prepared with corn, MCS1, MCS2 and MCS3 at 2% dry weight by solution incorporation method

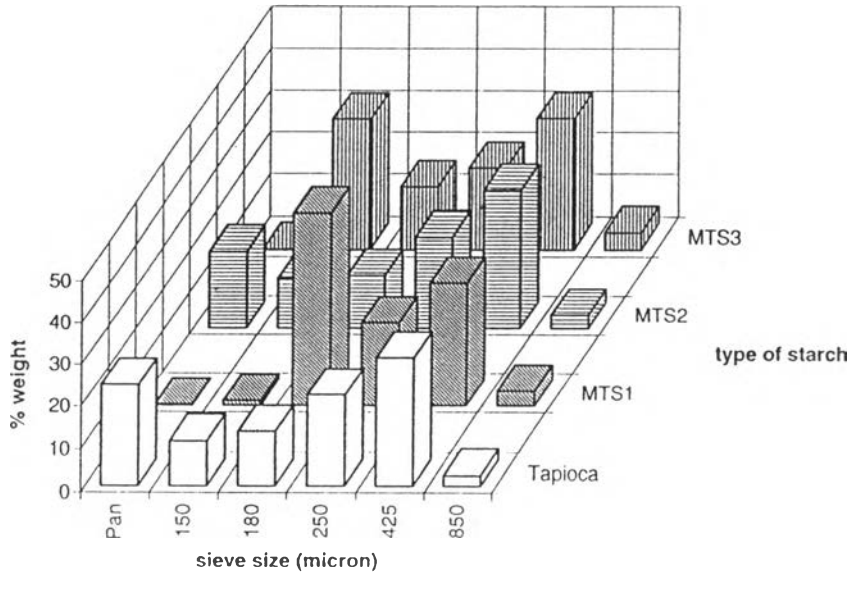

Figure **26** Histograms for particle size distribution of paracetamol granules prepared with tapioca, MTS1, MTS2 and MTS3 at 1% dry weight by solution incorporation method

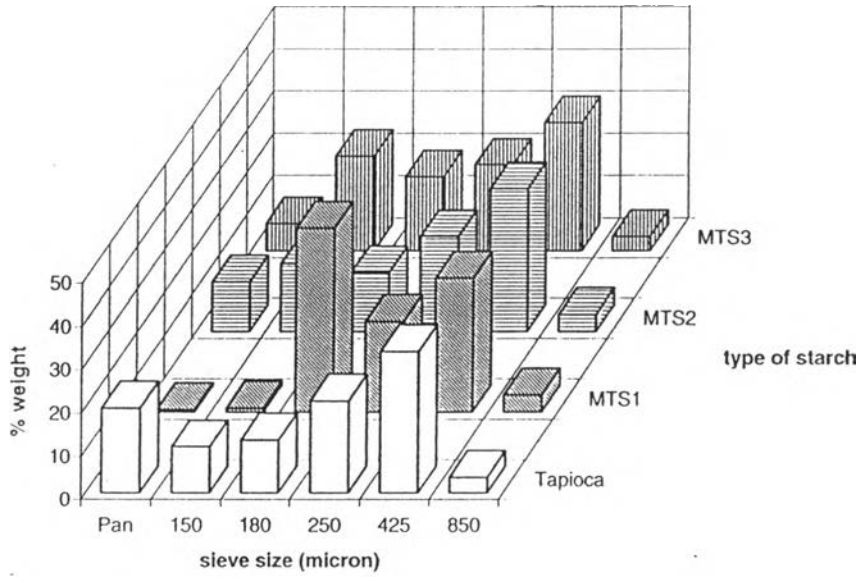

Figure **27** Histograms for particle size distribution of paracetamol granules prepared with tapioca, MTS1, MTS2 and MTS3 at 1.5% dry weight by solution incorporation method

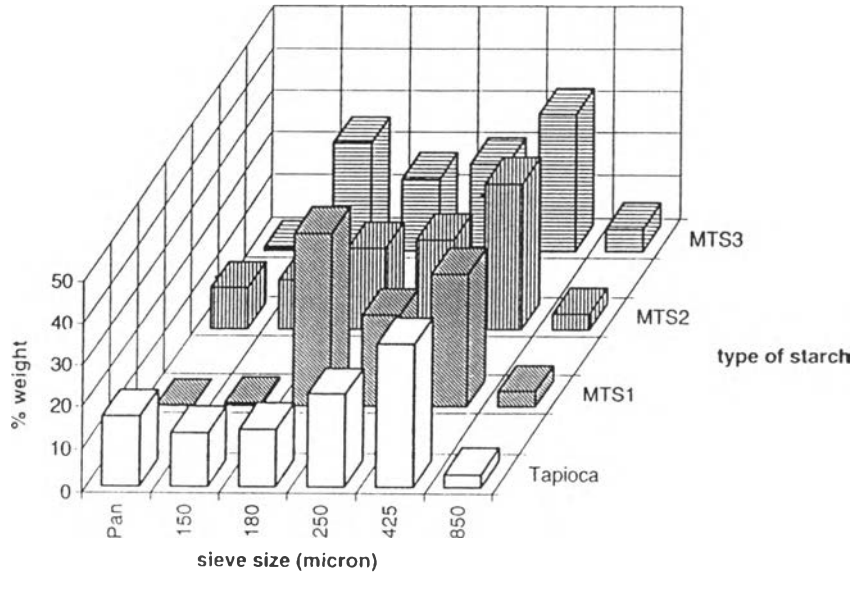

Figure **28** Histograms for particle size distribution of paracetamol granules prepared with tapioca, MTS1, MTS2 and MTS3 at 2% dry weight by solution incorporation method

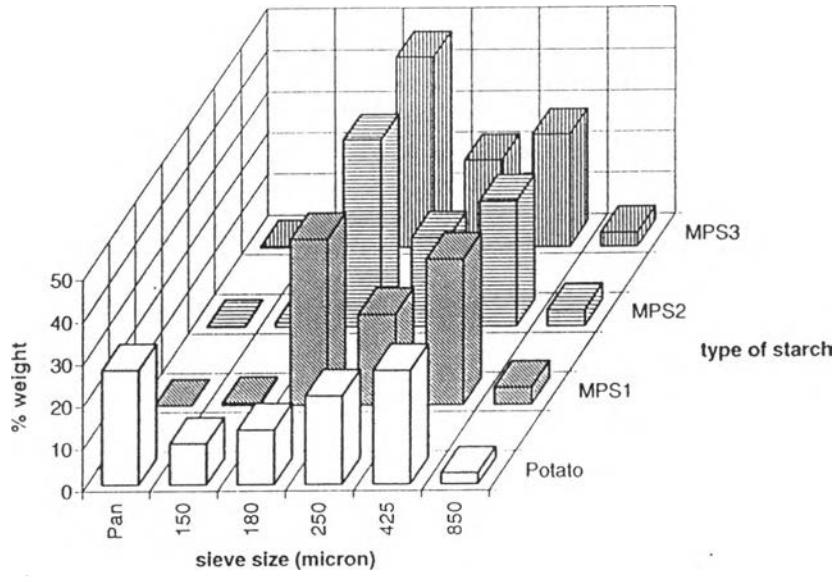

Figure **29** Histograms for particle size distribution of paracetamol granules prepared with potato, MPS1, MPS2 and MPS3 at 1% dry weight by solution incorporation method

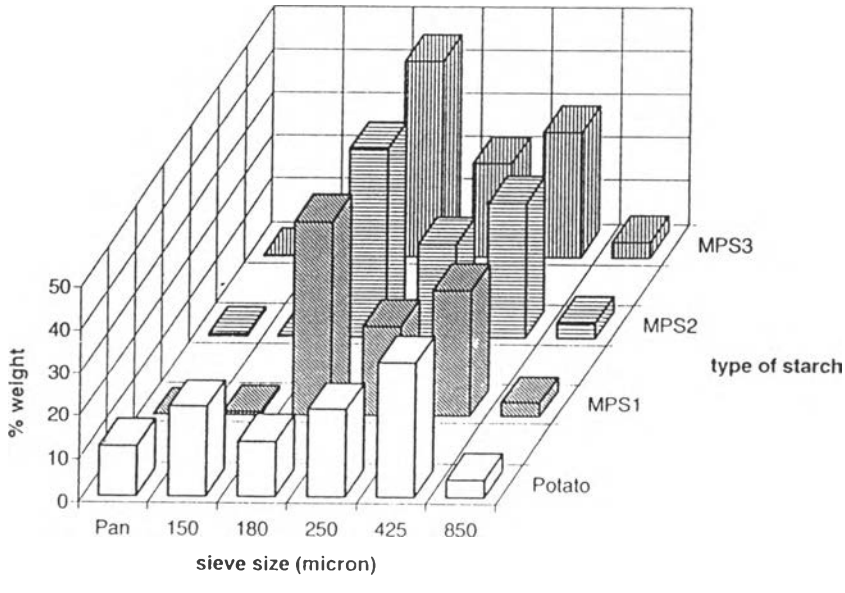

Figure **30** Histograms for particle size distribution of paracetamol granules prepared with potato, MPS1, MPS2 and MPS3 at 1.5% dry weight by solution incorporation method

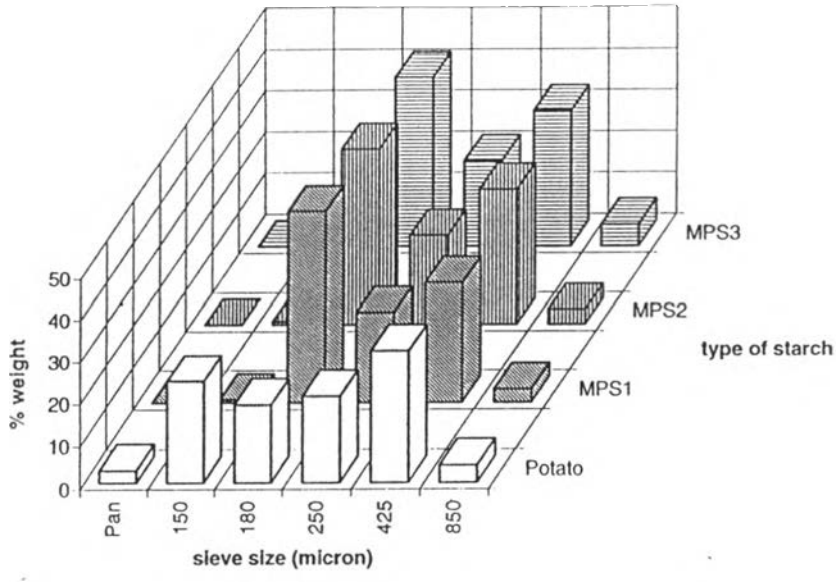

Figure **31** Histograms for particle size distribution of paracetamol granules prepared with potato, MPS1, MPS2 and MPS3 at 2% dry weight by solution incorporation method

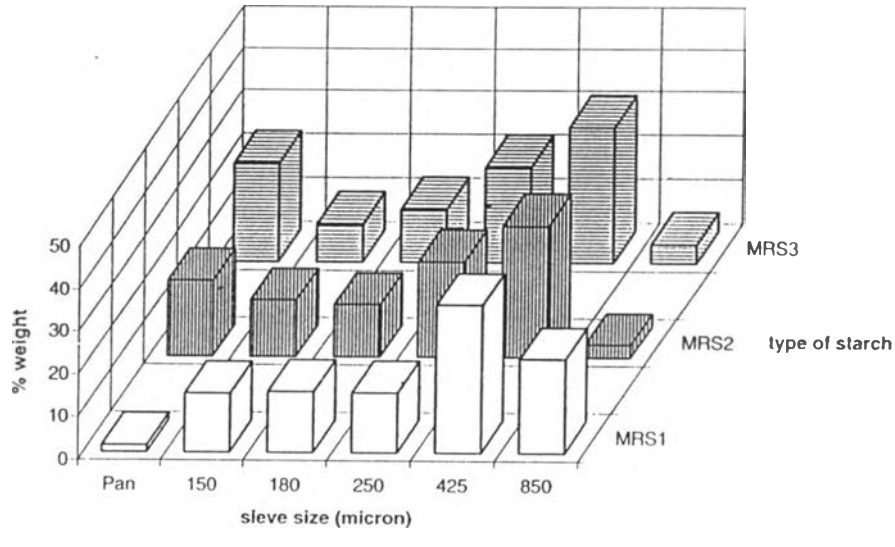

Figure **32** Histograms for particle size distribution of paracetamol granules prepared with MRS1, MRS2 and MRS3 at 1% dry weight by dry incorporation method

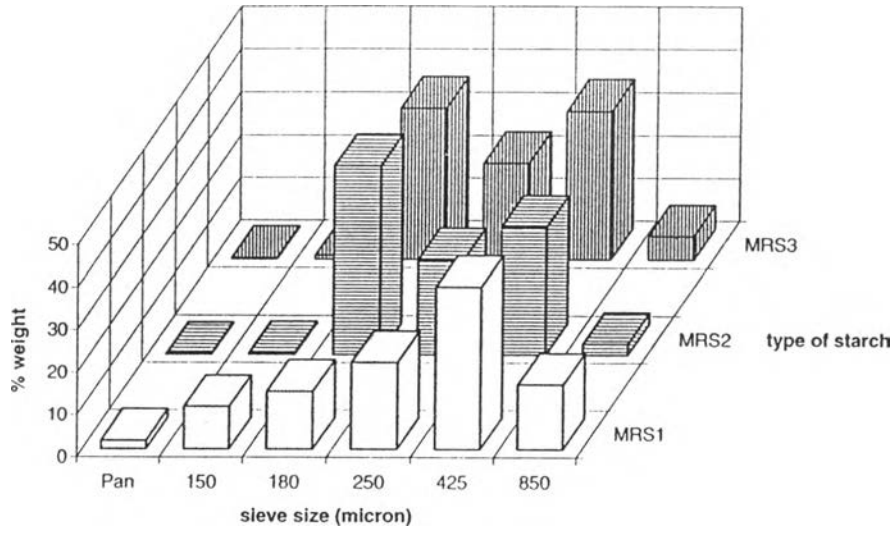

Figure **33** Histograms for particle size distribution of paracetamol granules prepared with MRS1, MRS2 and MRS3 at 1.5% dry weight by dry incorporation method

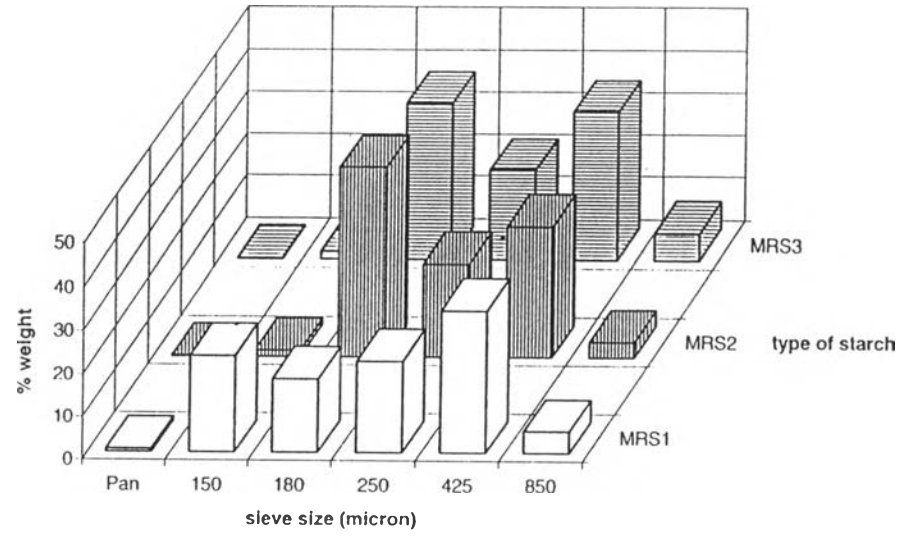

Figure **34** Histograms for particle size distribution of paracetamol granules prepared with MRS1, MRS2 and MRS3 at 2% dry weight by dry incorporation method

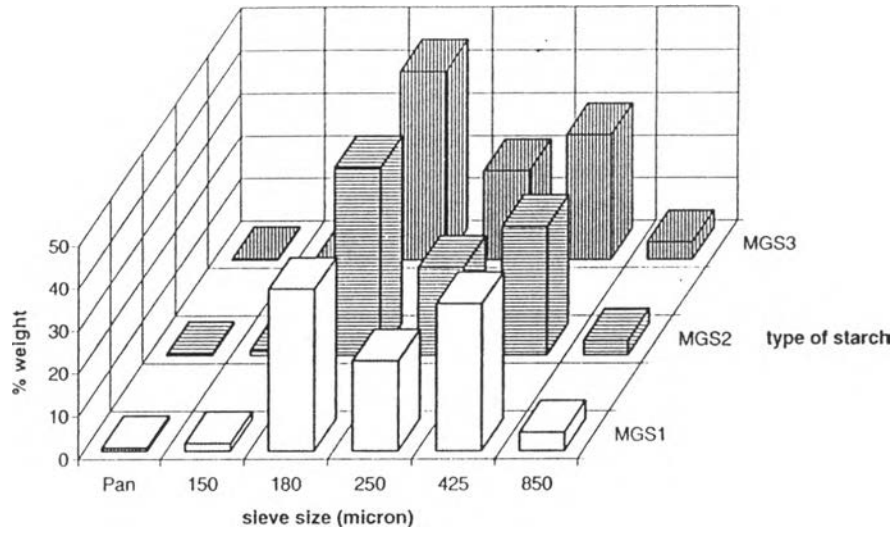

Figure **35** Histograms for particle size distribution of paracetamol granules prepared with MGS1, MGS2 and MGS3 at 1% dry weight by dry incorporation method

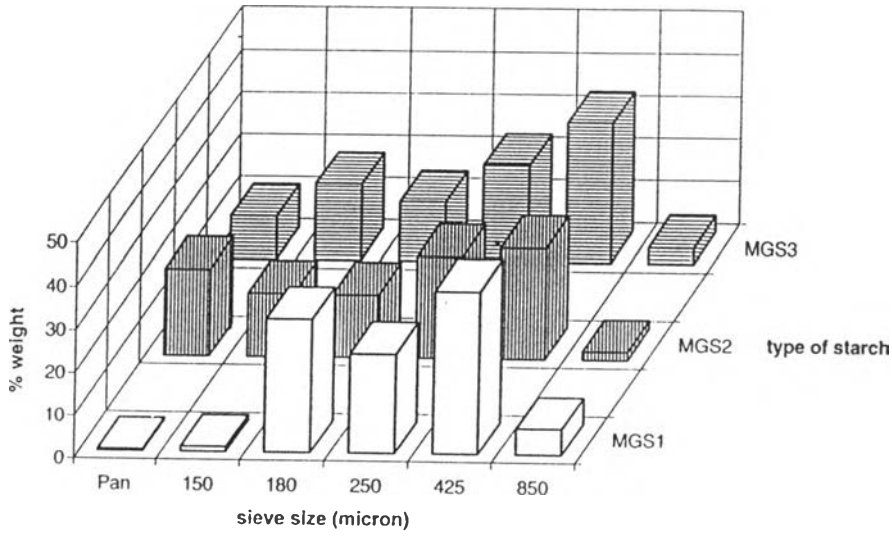

Figure **36** Histograms for particle size distribution of paracetamol granules prepared with MGS1, MGS2 and MGS3 at 1.5% dry weight by dry incorporation method

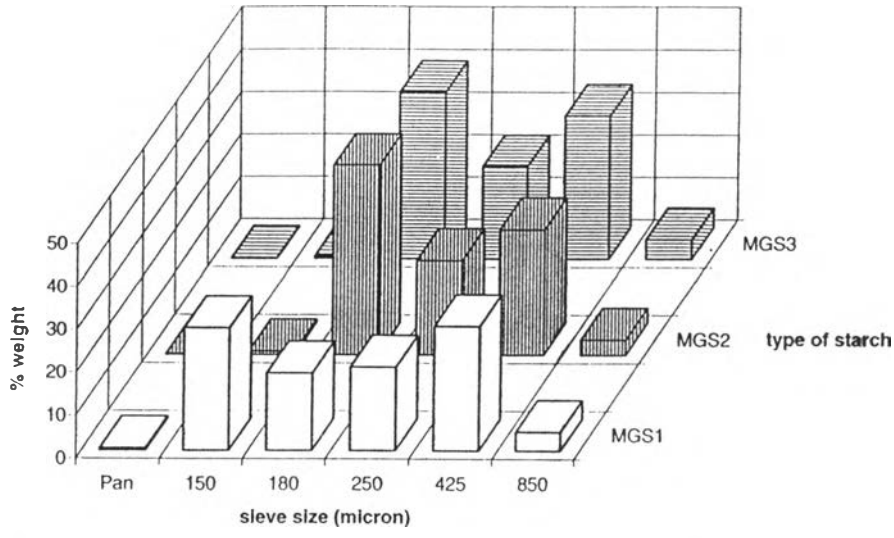

Figure **37** Histograms for particle size distribution of paracetamol granules prepared with MGS1, MGS2 and MGS3 at 2% dry weight by dry incorporation method

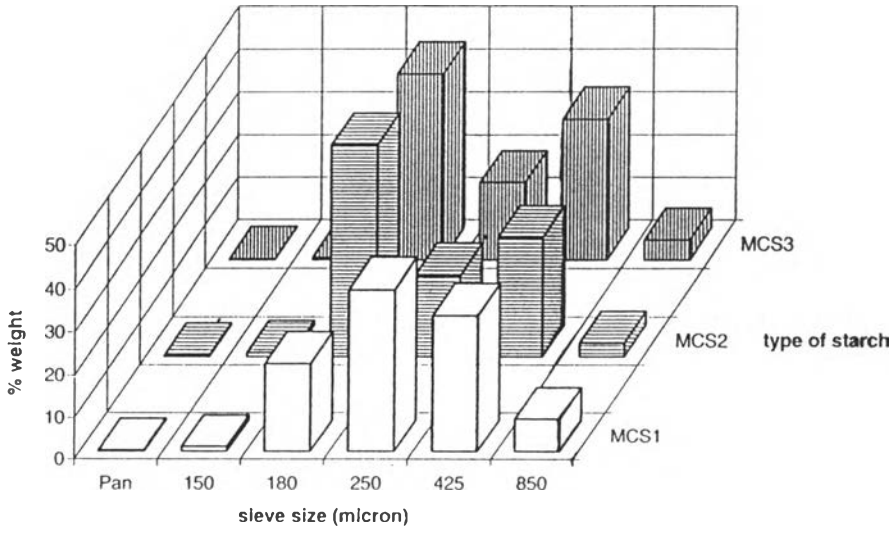

Figure **38** Histograms for particle size distribution of paracetamol granules prepared with MCS1, MCS2 and MCS3 at 1% dry weight by dry incorporation method

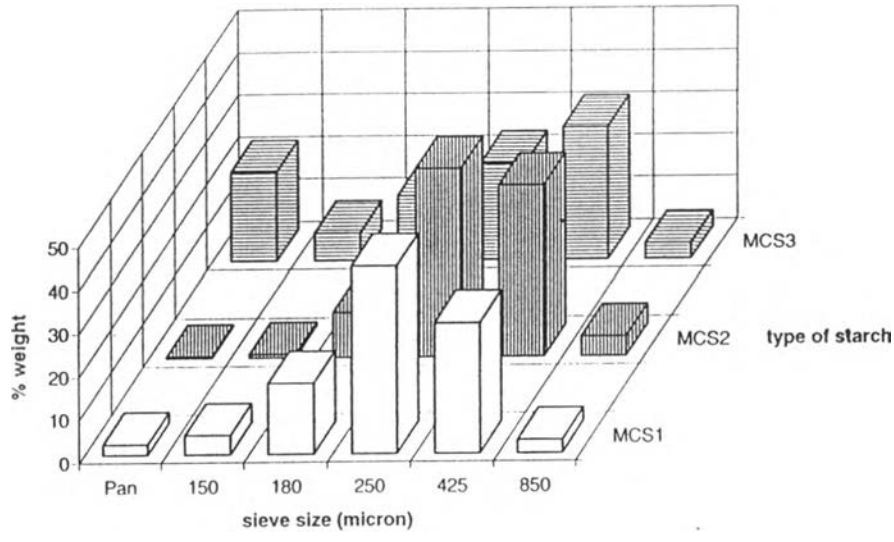

Figure **39** Histograms for particle size distribution of paracetamol granules prepared with MCS1, MCS2 and MCS3 at 1.5% dry weight by dry incorporation method

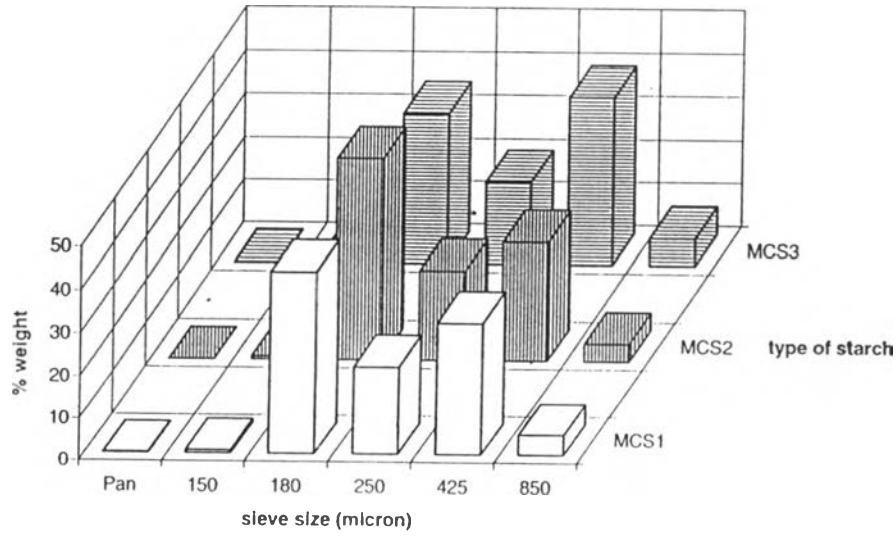

Figure **40** Histograms for particle size distribution of paracetamol granules prepared with MCS1, MCS2 and MCS3 at 2% dry weight by dry incorporation method

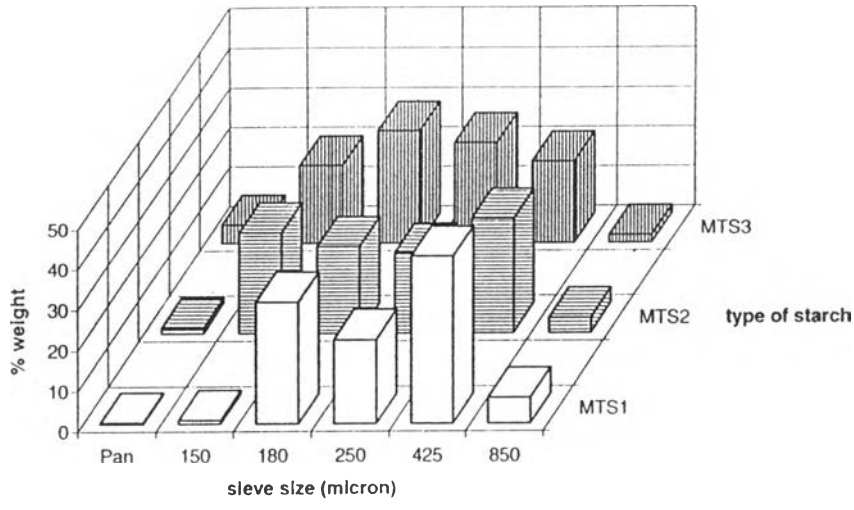

Figure **41** Histograms for particle size distribution of paracetamol granules prepared with MTS1, MTS2 and MTS3 at 1% dry weight by dry incorporation method

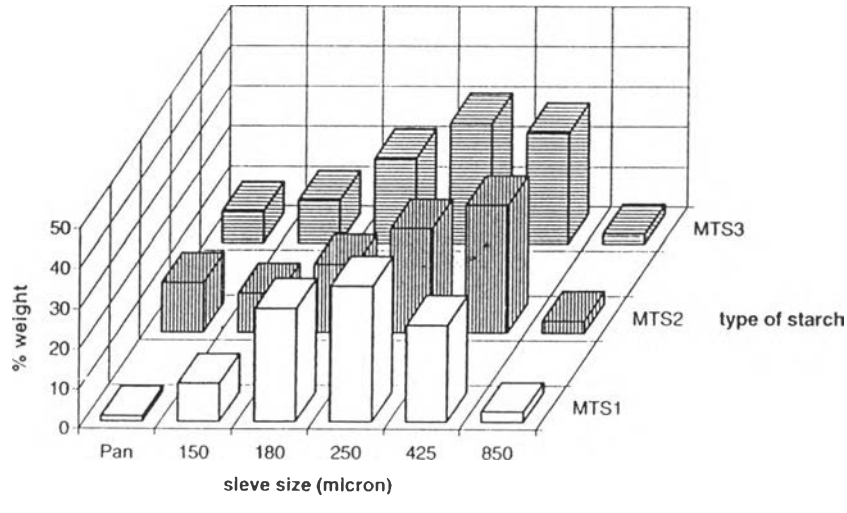

Figure **42** Histograms for particle size distribution of paracetamol granules prepared with MTS1, MTS2 and MTS3 at 1.5% dry weight by dry incorporation method

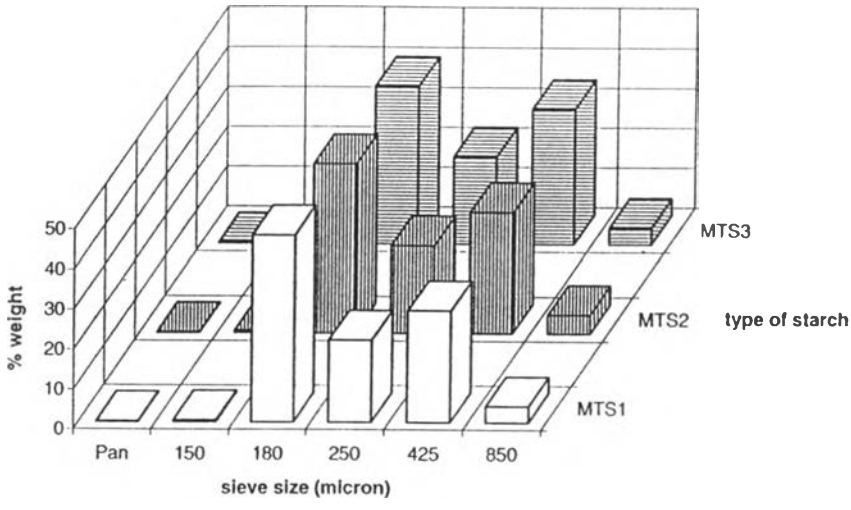

Figure 43 Histograms for particle size distribution of paracetamol granules prepared with MTS1, MTS2 and MTS3 at 2% dry weight by dry incorporation method

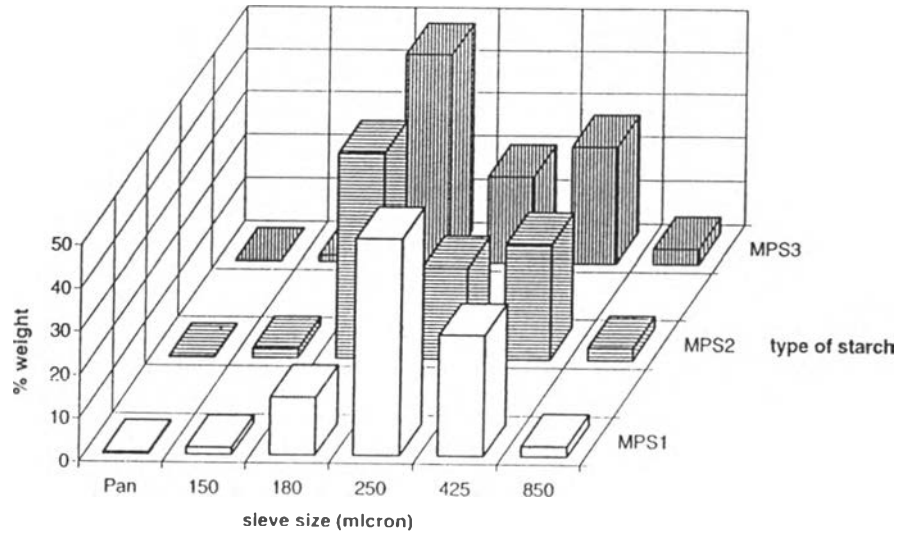

Figure 44 Histograms for particle size distribution of paracetamol granules prepared with MPS1, MPS2 and MPS3 at 1% dry weight by dry incorporation method

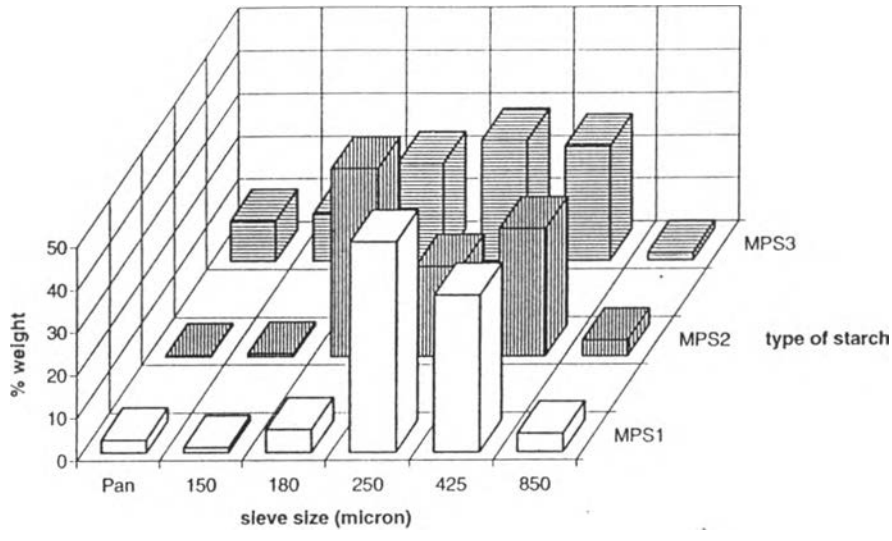

Figure 45 Histograms for particle size distribution of paracetamol granules prepared with MPS1, MPS2 and MPS3 at 1.5% dry weight by dry incorporation method

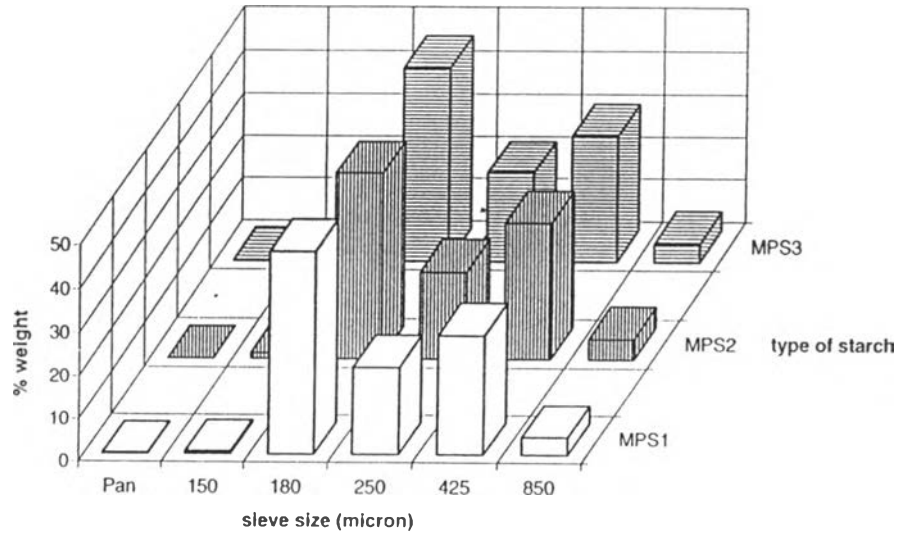

Figure 46 Histograms for particle size distribution of paracetamol granules prepared with MPS1, MPS2 and MPS3 at 2% dry weight by dry incorporation method

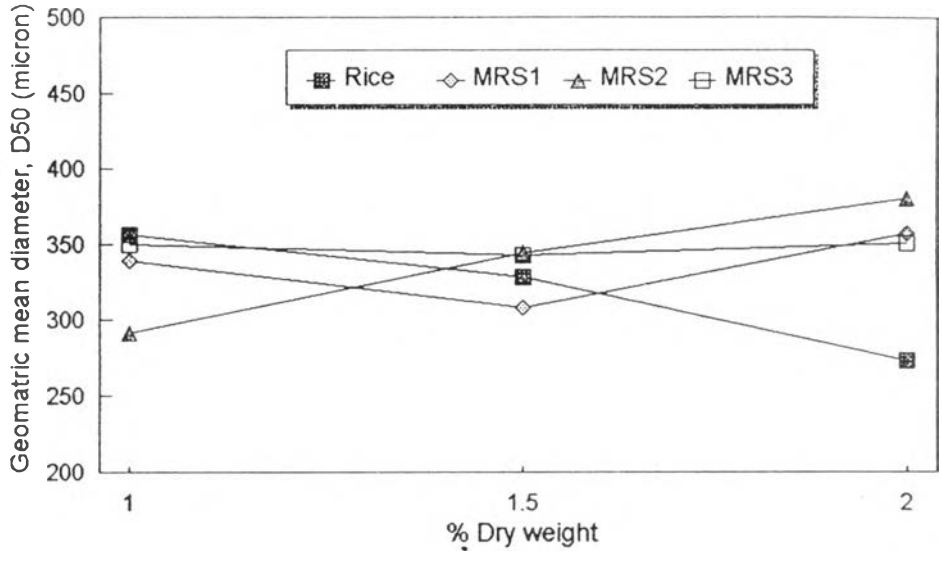

Figure **47** Geometric mean diameter (D_{50}) of paracetamol granules prepared with rice, MRS1, MRS2 or MRS3 by solution incorporation method.

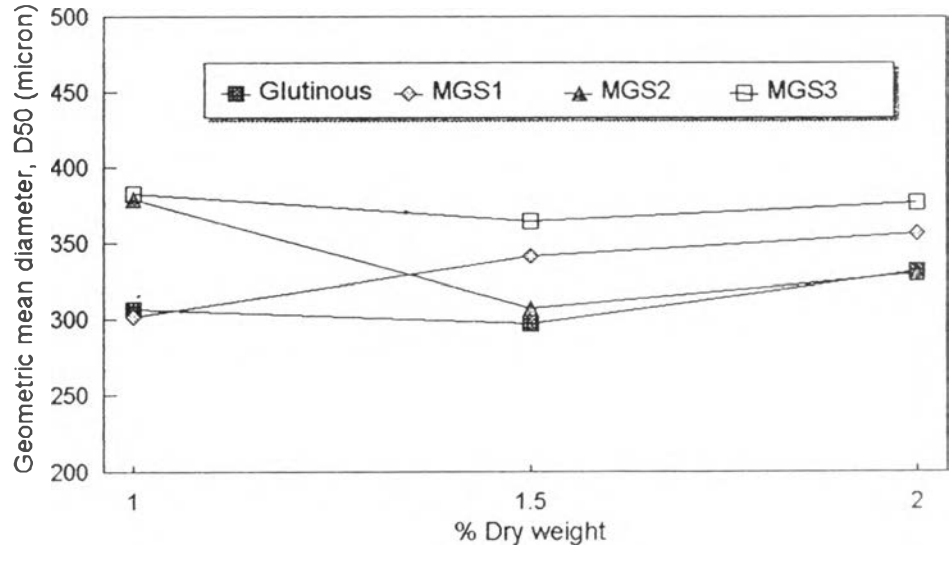

Figure **48** Geometric mean diameter (D_{50}) of paracetamol granules prepared with glutinous rice, MGS1, MGS2 or MGS3 by solution incorporation method.

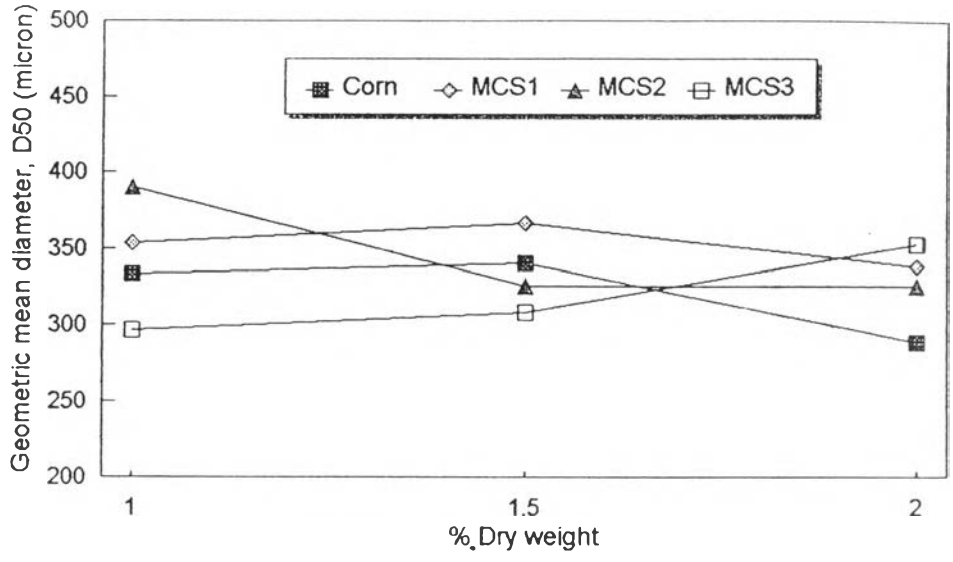

Figure **49** Geometric mean diameter (D_{50}) of paracetamol granules prepared with corn, MCS1, MCS2 or MCS3 by solution incorporation method.

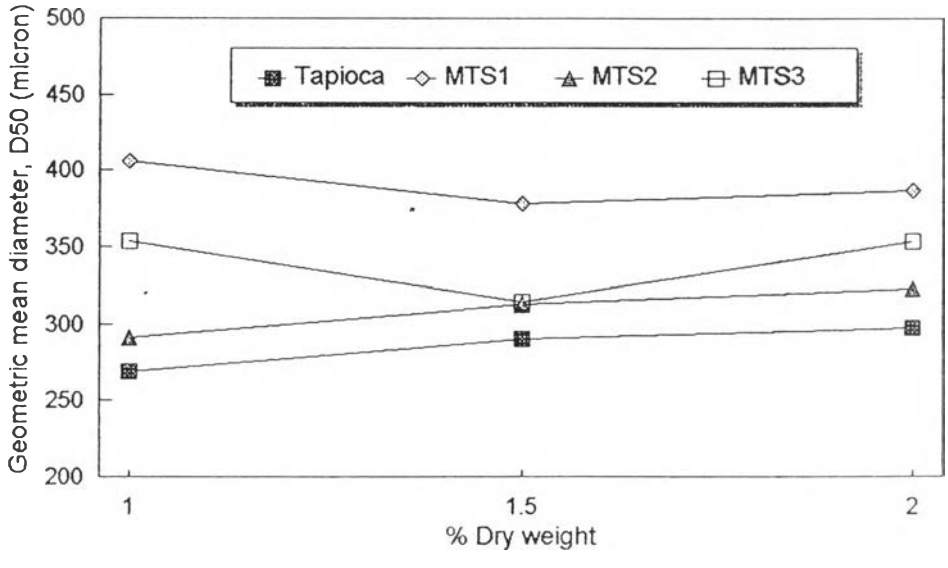

Figure **50** Geometric mean diameter (D_{50}) of paracetamol granules prepared with tapioca, MTS1, MTS2 or MTS3 by solution incorporation method.

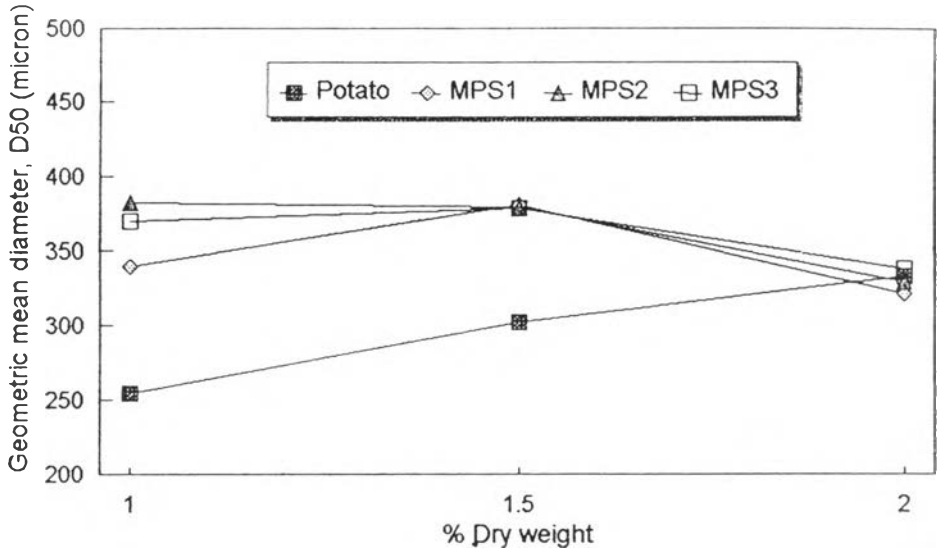

Figure **51** Geometric mean diameter (D_{50}) of paracetamol granules prepared with potato, MPS1, MPS2 or MPS3 by solution incorporation method.

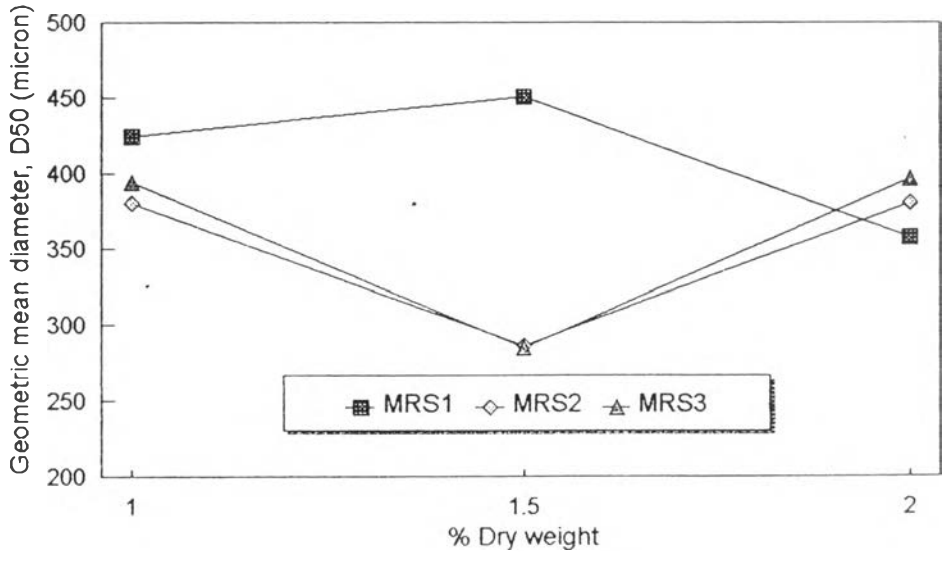

Figure **52** Geometric mean diameter (D_{50}) of paracetamol granules prepared with MRS1, MRS2 or MRS3 by dry incorporation method.

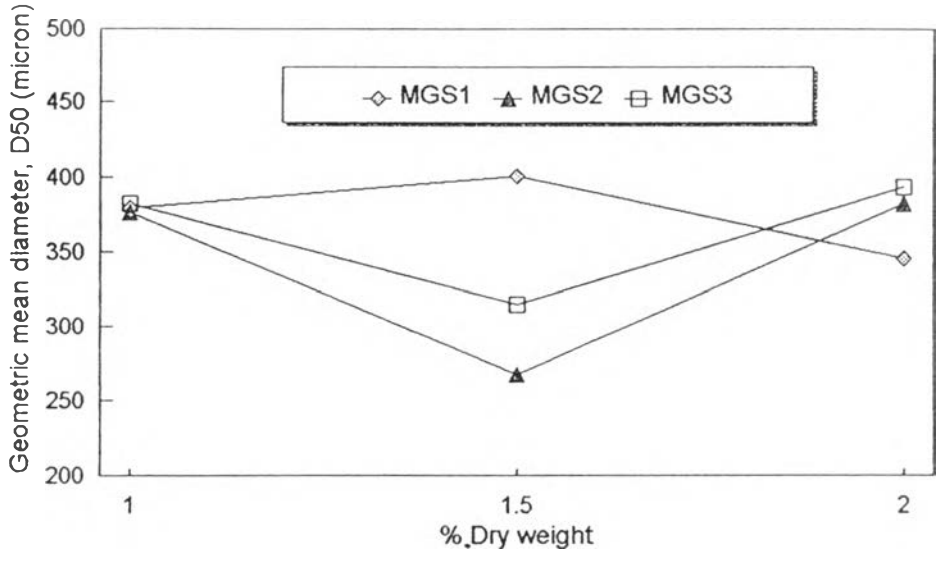

Figure **53** Geometric mean diameter (D_{50}) of paracetamol granules prepared with MGS1, MGS2 or MGS3 by dry incorporation method.

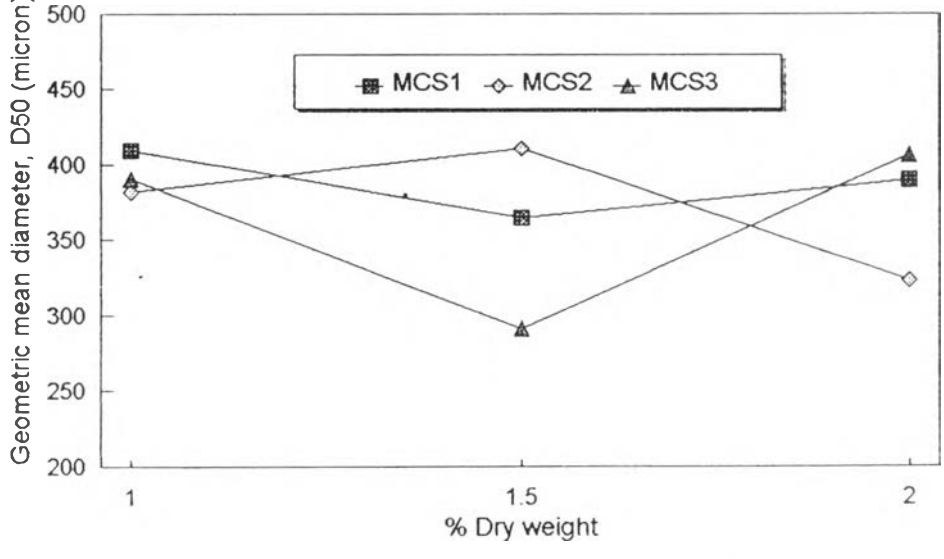

Figure **54** Geometric mean diameter (D_{50}) of paracetamol granules prepared with MCS1, MCS2 or MCS3 by dry incorporation method.

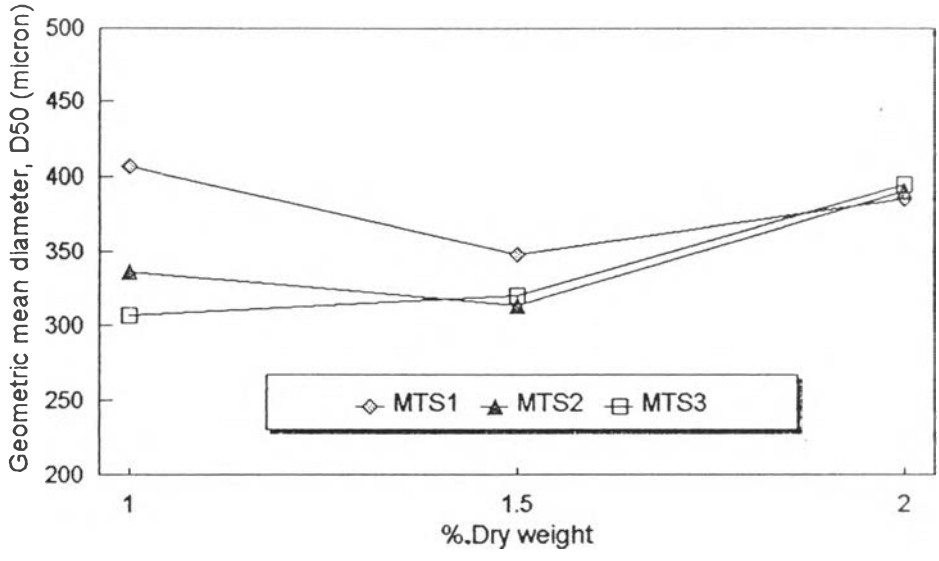

Figure **55** Geometric mean diameter (D_{50}) of paracetamol granules prepared with MTS1, MTS2 or MTS3 by dry incorporation method.

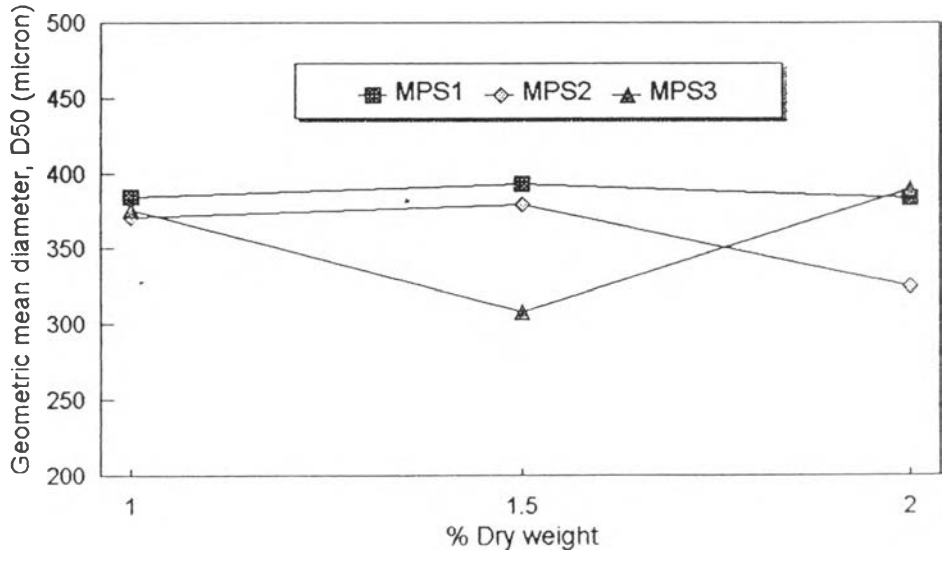

Figure **56** Geometric mean diameter (D_{50}) of paracetamol granules prepared with MPS1, MPS2 or MPS3 by dry incorporation method.

2.1.2. Bulk density, tapped density and percent compressibility

Tables 5 and 6 display the bulk density, tapped density and percent compressibility of paracetamol granules prepared by solution and dry incorporation methods, respectively. By solution incorporation method, the bulk density of the granules containing the native starches was apparent to be slightly lower than of the granules containing modified starches whereas percent compressibility was higher. The tapped density of the granules prepared by the native starches and the modified starches were nearly equal. The bulk density, the tapped density and percent compressibility of the granules containing various types and various contents of the modified starches exhibited no different. With dry incorporation method, the bulk density of the granules using modified starch was similar to that obtained by solution incorporation method but the tapped density and the percent compressibility were lower.

2.1.3. Flow rate and angle of repose

The flow rate and angle of repose of the granules are shown in Tables 7-8. The granules prepared by solution incorporation method seemed to have lower angle of repose and higher flow rate than which prepared by dry incorporation method. The flow rate and the angle of repose of the granules using either native or modified starch were varied.

Table **5** Bulk density, tapped density and percent compressibility of paracetamol granules prepared with various binders and concentrations by solution incorporation method.

Binder	Physical properties of granules								
	Bulk density (gm./ml)			Tapped density(gm/ml)			% Compressibility (%)		
	1%	1.5%	2%	1%	1.5%	2%	1%	1.5%	2%
Rice	0.37	0.39	0.36	0.60	0.59	0.60	38.12 (0.07)*	34.05 (0.24)*	40.28 (0.12)*
MRS1	0.40	0.39	0.41	0.60	0.59	0.60	33.33 (0.19)	32.89 (0.00)	32.88 (0.61)
MRS2	0.40	0.39	0.39	0.60	0.58	0.61	33.18 (1.24)	33.04 (0.25)	35.09 (0.58)
MRS3	0.40	0.39	0.40	0.59	0.58	0.60	33.04 (1.24)	32.60 (0.83)	33.48 (0.06)
Glutinous	0.39	0.39	0.37	0.60	0.60	0.58	35.76 (0.06)	35.06 (0.00)	35.53 (0.21)
MGS1	0.39	0.41	0.40	0.58	0.60	0.61	32.47 (0.00)	31.97 (0.21)	34.37 (0.26)
MGS2	0.41	0.41	0.41	0.60	0.60	0.60	31.98 (0.61)	32.12 (0.29)	32.12 (0.29)
MGS3	0.40	0.41	0.41	0.60	0.62	0.63	33.33 (0.00)	33.17 (1.34)	34.25 (0.00)
Corn	0.38	0.38	0.38	0.58	0.58	0.58	34.18 (0.00)	35.00 (0.00)	35.00 (0.00)
MCS1	0.38	0.39	0.38	0.59	0.59	0.60	35.99 (0.78)	34.77 (0.07)	37.50 (0.00)
MCS2	0.39	0.38	0.42	0.58	0.57	0.64	32.75 (0.08)	33.33 (0.53)	34.89 (0.08)
MCS3	0.42	0.41	0.42	0.67	0.66	0.65	37.21 (0.26)	38.29 (0.61)	34.43 (0.51)
Tapioca	0.37	0.37	0.35	0.60	0.60	0.58	37.89 (0.15)	39.15 (0.05)	39.41 (0.29)
MTS1	0.37	0.38	0.39	0.61	0.63	0.63	39.13 (0.14)	39.66 (0.53)	37.66 (0.00)
MTS2	0.38	0.38	0.40	0.61	0.62	0.63	38.75 (0.00)	38.26 (0.75)	36.56 (0.24)
MTS3	0.39	0.38	0.40	0.63	0.61	0.64	36.84 (0.00)	37.18 (0.00)	38.10 (0.55)
Potato	0.39	0.39	0.38	0.60	0.60	0.60	34.78 (0.24)	35.20 (0.06)	36.44 (0.22)
MPS1	0.40	0.38	0.40	0.60	0.61	0.62	32.88 (0.20)	36.97 (0.14)	35.56 (0.59)
MPS2	0.39	0.39	0.39	0.60	0.60	0.62	35.06 (0.71)	35.06 (0.00)	36.95 (1.52)
MPS3	0.41	0.39	0.40	0.61	0.60	0.62	33.78 (0.00)	35.78 (0.43)	35.68 (0.07)

* Standard deviation

Table **6** Bulk density, tapped density and percent compressibility of paracetamol granules prepared with various binders and concentrations by dry incorporation method.

Binder	Physical properties of granules								
	Bulk density (gm./ml)			Tapped density(gm/ml)			% Compressibility (%)		
	1%	1.5%	2%	1%	1.5%	2%	1%	1.5%	2%
MRS1	0.43	0.42	0.35	0.55	0.55	0.56	21.43 (0.00)*	23.61 (0.00)*	36.96 (0.18)*
MRS2	0.41	0.35	0.39	0.57	0.49	0.58	28.67 (2.08)	28.24 (0.11)	31.58 (0.00)
MRS3	0.42	0.40	0.40	0.56	0.55	0.57	24.93 (1.46)	28.41 (0.24)	29.91 (0.47)
MGS1	0.41	0.42	0.41	0.56	0.59	0.61	26.03 (0.00)	29.17 (0.00)	33.33 (0.61)
MGS2	0.41	0.36	0.40	0.56	0.52	0.60	25.68 (0.35)	30.37 (0.04)	33.33 (0.00)
MGS3	0.41	0.39	0.41	0.56	0.55	0.60	26.94 (0.63)	29.13 (0.45)	31.51 (0.00)
MCS1	0.42	0.34	0.40	0.55	0.47	0.60	23.61 (0.00)	27.27 (1.29)	33.03 (0.27)
MCS2	0.41	0.41	0.41	0.56	0.60	0.61	27.03 (0.00)	32.43 (0.00)	32.42 (0.63)
MCS3	0.43	0.34	0.41	0.60	0.50	0.63	28.57 (0.00)	32.58 (0.00)	34.25 (0.00)
MTS1	0.41	0.36	0.39	0.56	0.52	0.61	26.03 (0.00)	30.95 (0.00)	35.65 (1.55)
MTS2	0.41	0.35	0.41	0.56	0.50	0.58	26.04 (0.58)	29.14 (0.64)	30.63 (0.61)
MTS3	0.36	0.36	0.39	0.53	0.50	0.60	31.33 (0.00)	27.71 (0.00)	34.21 (0.00)
MPS1	0.39	0.39	0.40	0.50	0.60	0.60	21.05 (0.00)	34.21 (0.00)	33.33 (0.00)
MPS2	0.43	0.41	0.41	0.60	0.58	0.57	27.74 (2.06)	30.09 (0.30)	27.97 (1.89)
MPS3	0.40	0.31	0.40	0.60	0.53	0.60	33.33 (0.00)	40.63 (0.00)	33.47 (1.63)

* Standard deviation

Table **7** Flow rate and angle of repose of paracetamol granules prepared with various binders and concentrations by solution incorporation method.

Binder	Flow rate (gm/min.)			Angle of repose		
	1%	1.5%	2%	1%	1.5%	2%
Rice	188.55+36.88	243.90+0.00	174.55+9.44	35.12+1.31	34.12+0.62	37.84+0.43
MRS1	225.00+0.00	204.78+8.52	216.79+58.26	33.79+0.17	37.41+0.94	33.29+0.17
MRS2	221.13+5.62	209.66+13.93	226.16+19.86	34.18+0.61	34.73+0.62	32.80+0.00
MRS3	226.29+4.66	206.42+8.63	225.79+21.61	33.89+0.35	34.47+0.16	33.89+0.17
Glutinous	229.85+4.46	208.65+7.12	228.55+2.76	35.33+0.75	38.34+0.16	35.67+0.86
MGS1	223.72+6.43	226.92+3.33	208.88+15.74	34.36+1.38	35.17+0.00	36.77+0.18
MGS2	231.92+7.57	195.52+2.02	218.63+1.52	36.25+0.00	37.01+0.44	34.58+0.51
MGS3	203.92+6.79	194.17+4.35	235.17+10.10	37.05+0.42	36.10+0.73	34.67+0.61
Corn	225.00+0.00	200.00+0.00	209.32+2.43	36.87+0.00	35.70+0.48	35.42+0.00
MCS1	206.27+7.30	195.24+2.23	198.55+2.51	36.46+0.36	36.35+0.18	34.29+0.00
MCS2	201.51+2.62	216.00+9.17	167.27+4.70	36.51+1.25	35.97+0.48	33.79+0.17
MCS3	201.30+3.50	191.04+7.95	169.02+32.76	36.55+0.73	35.90+0.59	33.78+1.03
Tapioca	200.00+0.00	222.29+4.69	156.15+21.44	37.08+0.18	35.62+0.35	39.09+0.74
MTS1	198.55+2.51	192.83+3.42	166.75+6.84	39.25+0.19	36.11+1.20	38.65+1.15
MTS2	178.42+19.79	199.76+4.21	208.33+14.43	37.06+0.81	37.05+0.42	37.59+0.80
MTS3	223.76+14.59	199.30+3.36	169.09+9.44	36.10+1.33	38.82+2.29	39.80+0.00
Potato	207.14+10.10	225.00+0.00	198.55+2.51	36.14+0.16	35.13+0.50	41.28+0.00
MPS1	203.37+4.04	184.21+9.04	214.71+0.74	38.55+0.19	39.30+0.90	38.50+0.00
MPS2	192.63+11.43	179.00+0.00	210.59+15.10	38.65+0.82	40.04+0.95	39.45+1.14
MPS3	225.59+6.40	181.15+4.23	211.26+17.59	39.14+0.00	39.52+0.65	38.23+0.47

Table **8** Flow rate and angle of repose of paracetamol granules prepared with various binders and concentrations by dry incorporation method.

Binder	Flow rate (gm/min.)			Angle of repose		
	1%	1.5%	2%	1%	1.5%	2%
MRS1	212.50+17.68	215.02+5.47	171.43+0.00	35.36+0.32	36.83+1.18	38.11+0.84
MRS2	119.74+1.21	155.41+18.46	242.64+13.38	36.52+0.47	35.78+0.43	34.27+1.00
MRS3	161.51+14.60	133.45+4.95	159.09+7.88	35.93+0.18	36.25+0.00	39.73+0.99
MGS1	214.94+5.10	202.62+18.06	223.17+3.17	36.33+0.70	38.24+1.86	37.67+1.43
MGS2	211.09+11.09	161.23+31.53	230.00+8.66	36.59+0.48	35.86+0.34	36.51+1.25
MGS3	197.30+6.51	197.10+2.51	191.88+10.52	35.80+0.33	35.66+0.77	40.99+1.73
MCS1	223.17+3.17	149.72+11.13	215.74+13.70	37.40+0.49	36.08+0.85	37.90+1.06
MCS2	191.52+6.94	203.85+4.85	196.40+3.29	37.00+0.72	37.99+1.44	39.03+0.18
MCS3	195.93+11.16	190.90+6.57	172.24+8.21	37.50+0.64	37.10+0.68	40.31+0.64
MTS1	141.46+1.28	185.45+21.54	214.55+9.37	36.26+0.28	38.08+1.75	36.74+1.23
MTS2	203.32+11.74	194.61+12.36	217.88+6.68	35.00+0.59	36.08+1.10	36.73+0.67
MTS3	198.55+2.51	176.78+8.94	186.67+11.55	38.67+1.13	35.21+1.15	41.94+0.94
MPS1	140.31+2.91	180.32+7.44	197.82+2.18	36.45+0.39	38.92+0.40	38.55+0.19
MPS2	190.08+8.81	188.41+4.18	200.90+10.80	36.05+0.55	38.07+0.94	35.46+0.50
MPS3	212.85+13.48	177.06+1.55	202.47+8.33	36.21+0.60	38.55+0.09	36.89+1.10

2.1.4. Percent friability

Histograms for percent friability of paracetamol granules are illustrated in Figures 57-66. In both incorporation method, as the modified starch content in the formula increased, the granule friability decreased. The granules containing the modified starches were stronger than which using native starches. However, the friability did not relate to the degree of substitution. Comparing between two incorporation method, the dry incorporation method produced the granules more friable than did the solution incorporation method.

2.1.5. Tablet thickness

The average thickness and the standard deviation of the tablets are presented in Tables 9-10. Generally, tablet thickness should be controlled within a 5% variation (Banker and Anderson, 1986). The tablets using the modified starches as tablet binders in both incorporation methods at any type, any degree of substitution and any content showed the consistent thickness. The thickness of the tablets using native starch and modified starch were not different.

2.1.6 Tablet hardness

The hardness of paracetamol tablets are depicted in Figures 67-76 and Tables 23-24 (in Appendix D). It could be seen that, as a binder weight increased, the hardness tended to increase. By solution incorporation method, the rank order of hardness at 1% binder weight

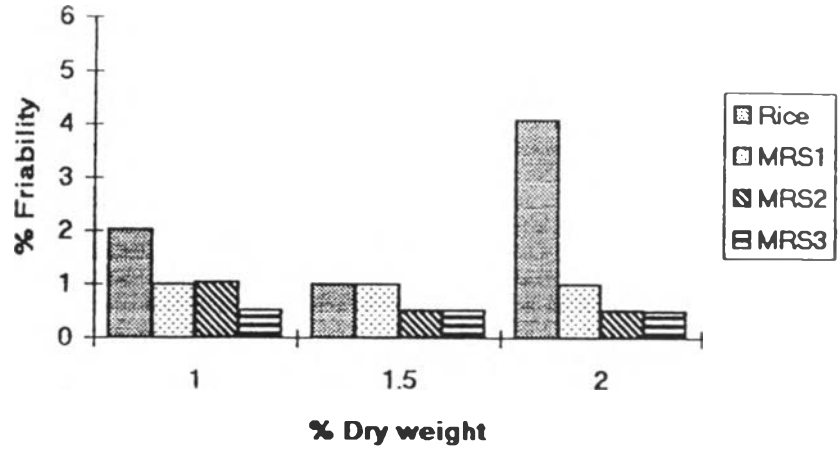

Figure **57** Histograms for the percent friability of paracetamol granules prepared with rice, MRS1, MRS2 or MRS3 by solution incorporation method.

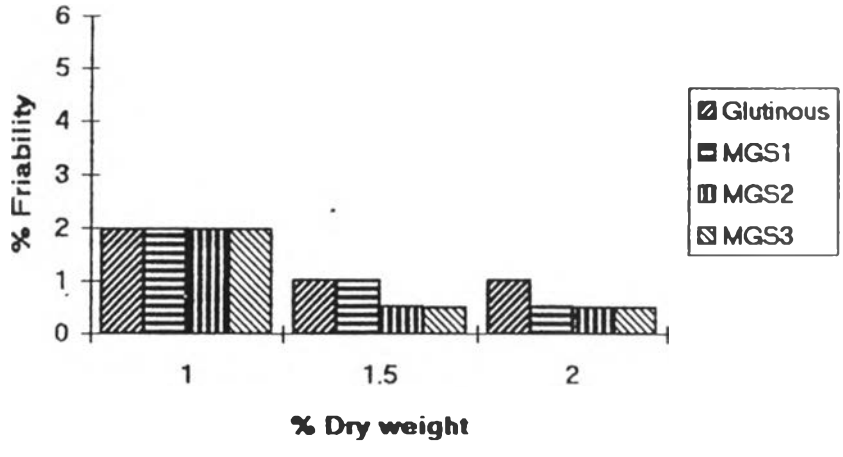

Figure **58** Histograms for the percent friability of paracetamol granules prepared with glutinous rice, MGS1, MGS2 or MGS3 by solution incorporation method.

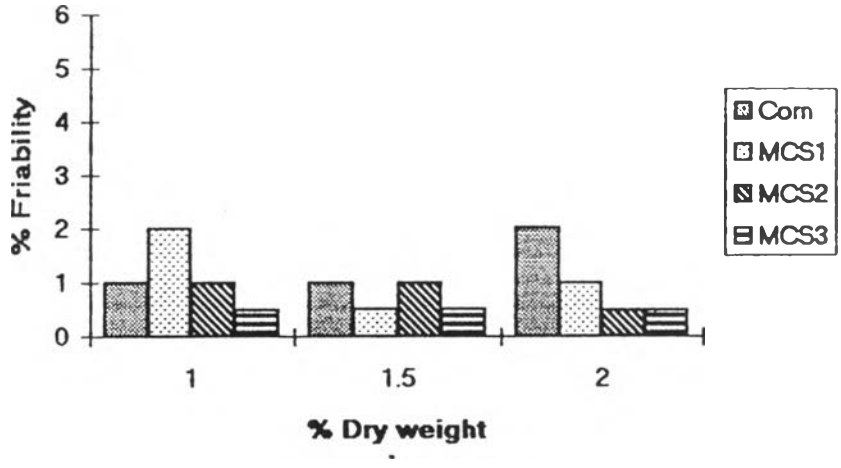

Figure **59** Histograms for the percent friability of paracetamol granules prepared with corn, MCS1, MCS2 or MCS3 by solution incorporation method.

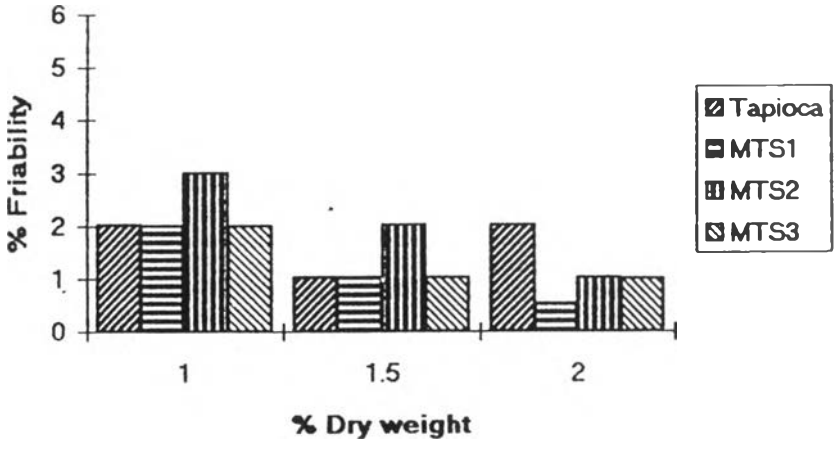

Figure **60** Histograms for the percent friability of paracetamol granules prepared with tapioca, MTS1, MTS2 or MTS3 by solution incorporation method.

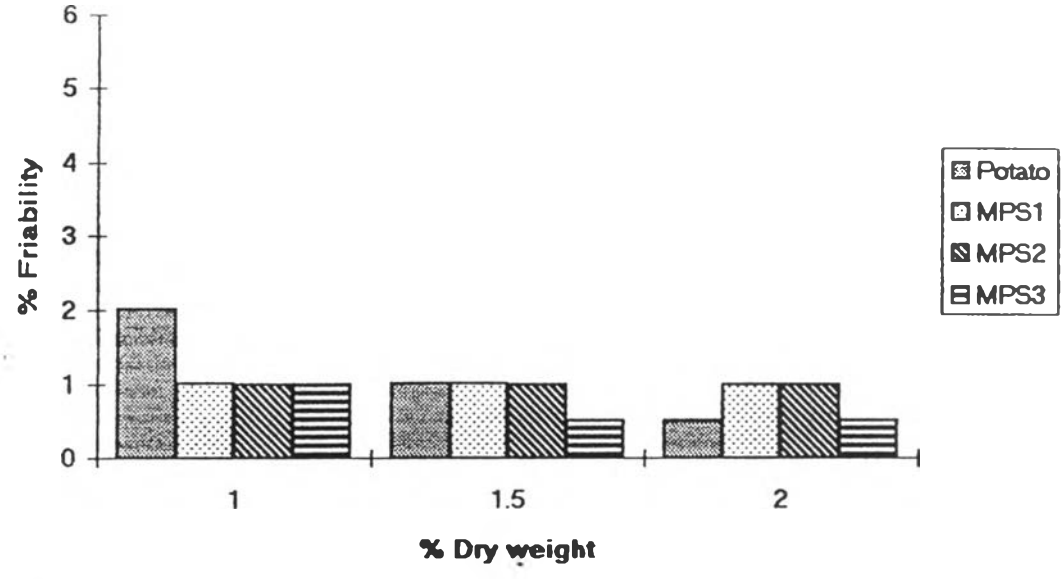

Figure **61** Histograms for the percent friability of paracetamol granules prepared with potato, MPS1, MPS2 or MPS3 by solution incorporation method.

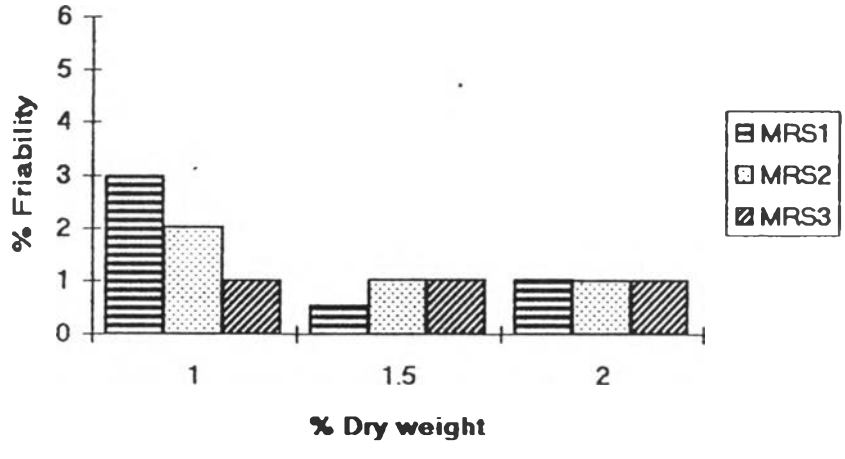

Figure **62** Histograms for the percent friability of paracetamol granules prepared with MRS1, MRS2 or MRS3 by dry incorporation method.

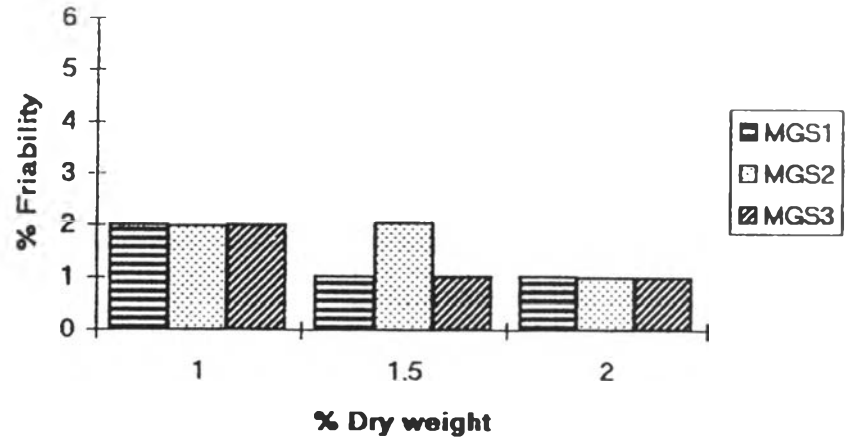

Figure **63** Histograms for the percent friability of paracetamol granules prepared with MGS1, MGS2 or MGS3 by dry incorporation method.

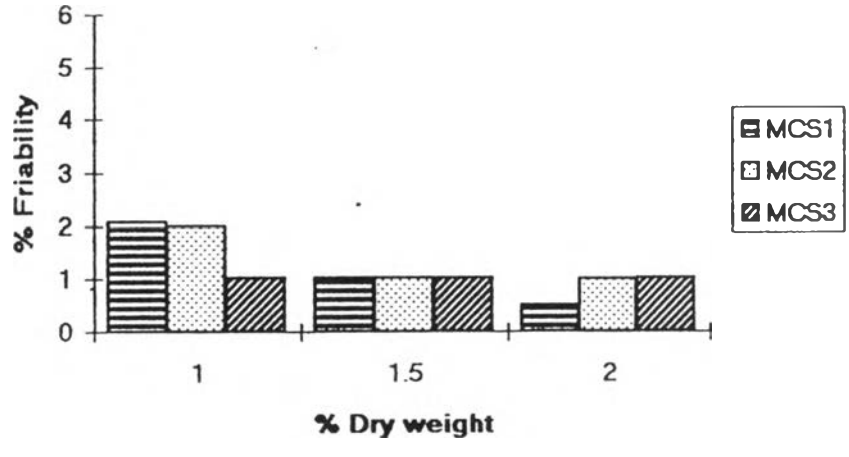

Figure **64** Histograms for the percent friability of paracetamol granules prepared with MCS1, MCS2 or MCS3 by dry incorporation method.

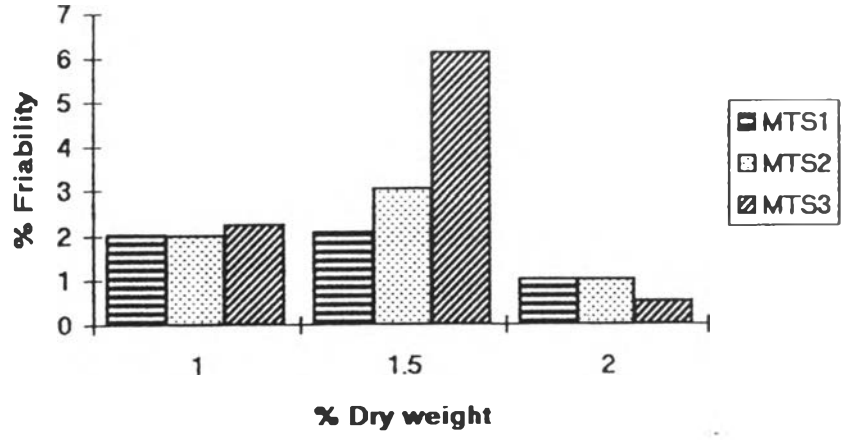

Figure **65** Histograms for the percent friability of paracetamol granules prepared with MTS1, MTS2 or MTS3 by dry incorporation method.

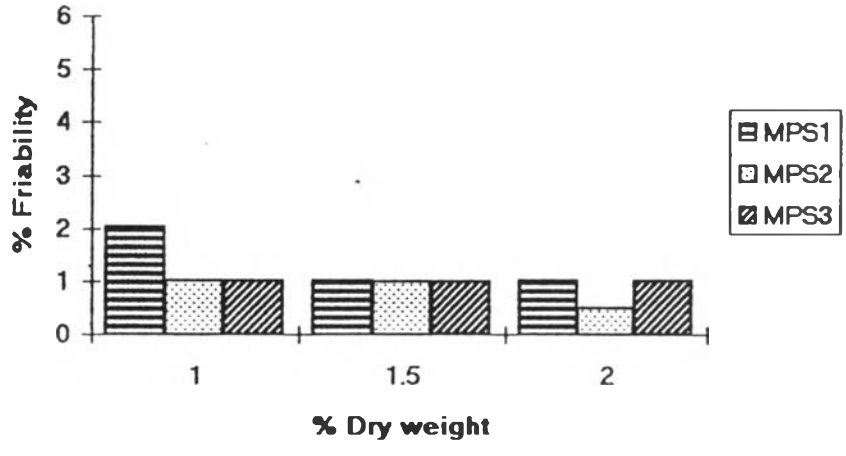

Figure **66** Histograms for the percent friability of paracetamol granules prepared with MPS1, MPS2 or MPS3 by dry incorporation method.

Table 9 Thickness of paracetamol tablets prepared with various binders and concentrations by solution incorporation method.

Binder	Thickness of paracetamol tablets (mm.)		
	1%	1.5%	2%
Rice	4.075 (0.010)*	4.159 (0.010)*	4.147 (0.007)*
MRS1	4.134 (0.013)	4.168 (0.015)	4.164 (0.011)
MRS2	4.163 (0.014)	4.181 (0.010)	4.190 (0.008)
MRS3	4.096 (0.020)	4.122 (0.010)	4.133 (0.013)
Glutinous	4.067 (0.007)	4.163 (0.009)	4.164 (0.007)
MGS1	4.089 (0.012)	4.179 (0.007)	4.162 (0.013)
MGS2	4.009 (0.007)	4.018 (0.010)	3.991 (0.018)
MGS3	4.159 (0.007)	4.170 (0.014)	4.003 (0.007)
Corn	4.139 (0.021)	4.159 (0.012)	4.157 (0.017)
MCS1	4.154 (0.013)	4.152 (0.006)	4.158 (0.013)
MCS2	4.087 (0.013)	4.132 (0.015)	4.083 (0.016)
MCS3	4.110 (0.013)	4.016 (0.020)	4.121 (0.013)
Tapioca	4.162 (0.009)	4.174 (0.018)	4.170 (0.012)
MTS1	4.154 (0.010)	4.138 (0.020)	4.124 (0.015)
MTS2	4.139 (0.011)	4.158 (0.013)	4.150 (0.009)
MTS3	4.122 (0.014)	4.135 (0.014)	4.132 (0.008)
Potato	4.161 (0.019)	4.167 (0.023)	4.153 (0.021)
MPS1	4.152 (0.013)	4.143 (0.018)	4.147 (0.008)
MPS2	4.154 (0.013)	4.158 (0.010)	4.158 (0.015)
MPS3	4.032 (0.023)	4.152 (0.010)	4.158 (0.016)

* Standard deviation

Table **10** Thickness of paracetamol tablets prepared with various binders and concentrations by dry incorporation method.

Binder	Thickness of paracetamol tablets (mm.)		
	1%	1.5%	2%
MRS1	4.135 (0.008)*	4.179 (0.014)*	4.173 (0.009)*
MRS2	4.145 (0.015)	4.140 (0.008)	4.196 (0.015)
MRS3	4.156 (0.012)	4.129 (0.016)	4.178 (0.013)
MGS1	4.141 (0.009)	4.146 (0.011)	4.183 (0.007)
MGS2	4.165 (0.016)	4.134 (0.016)	4.148 (0.010)
MGS3	4.159 (0.021)	4.142 (0.019)	4.162 (0.010)
MCS1	4.164 (0.012)	4.175 (0.014)	4.181 (0.010)
MCS2	4.141 (0.013)	4.118 (0.015)	4.173 (0.011)
MCS3	4.166 (0.010)	4.102 (0.016)	4.152 (0.010)
MTS1	4.131 (0.010)	4.150 (0.016)	4.162 (0.018)
MTS2	4.151 (0.017)	4.097 (0.019)	4.173 (0.008)
MTS3	4.159 (0.019)	4.148 (0.008)	4.144 (0.014)
MPS1	4.142 (0.009)	4.166 (0.007)	4.173 (0.008)
MPS2	4.119 (0.020)	4.152 (0.019)	4.207 (0.011)
MPS3	4.150 (0.012)	4.083 (0.018)	4.146 (0.010)

* Standard deviation

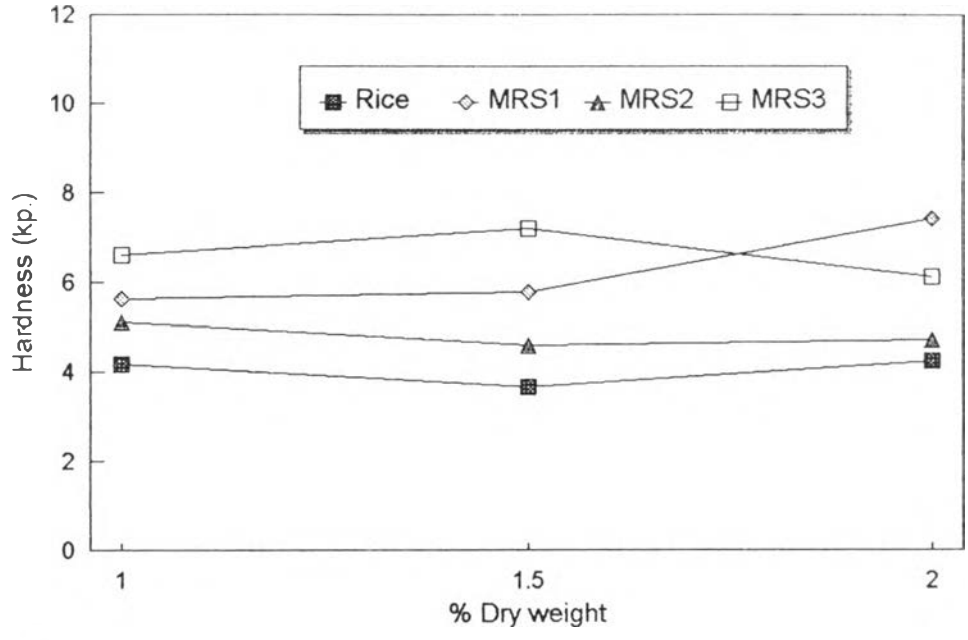

Figure **67** Hardness profiles of paracetamol tablets prepared with rice, MRS1, MRS2 or MRS3 at various concentrations by solution incorporation method.

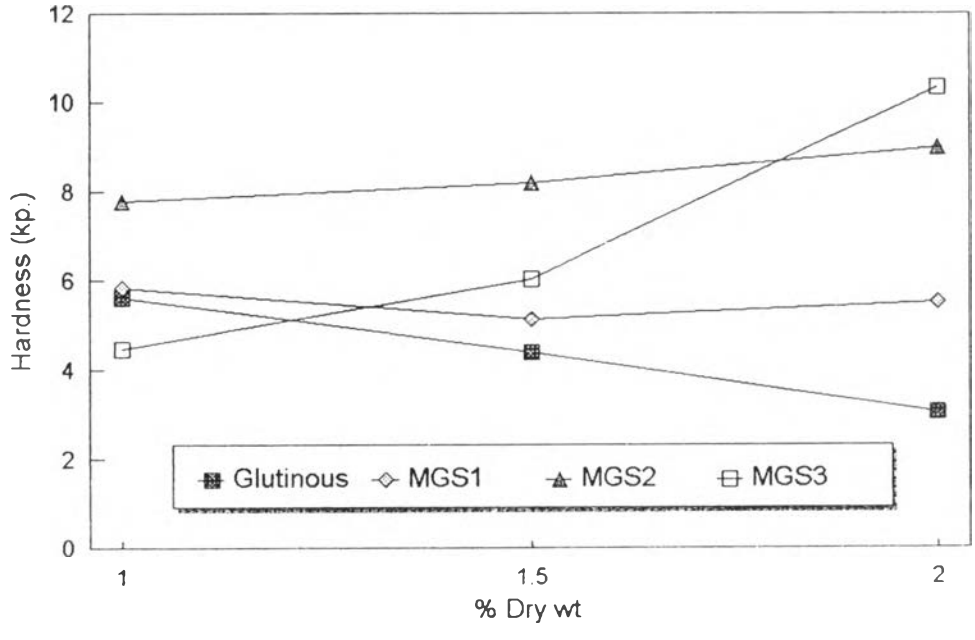

Figure **68** Hardness profiles of paracetamol tablets prepared with glutinous rice, MGS1, MGS2 or MGS3 at various concentrations by solution incorporation method.

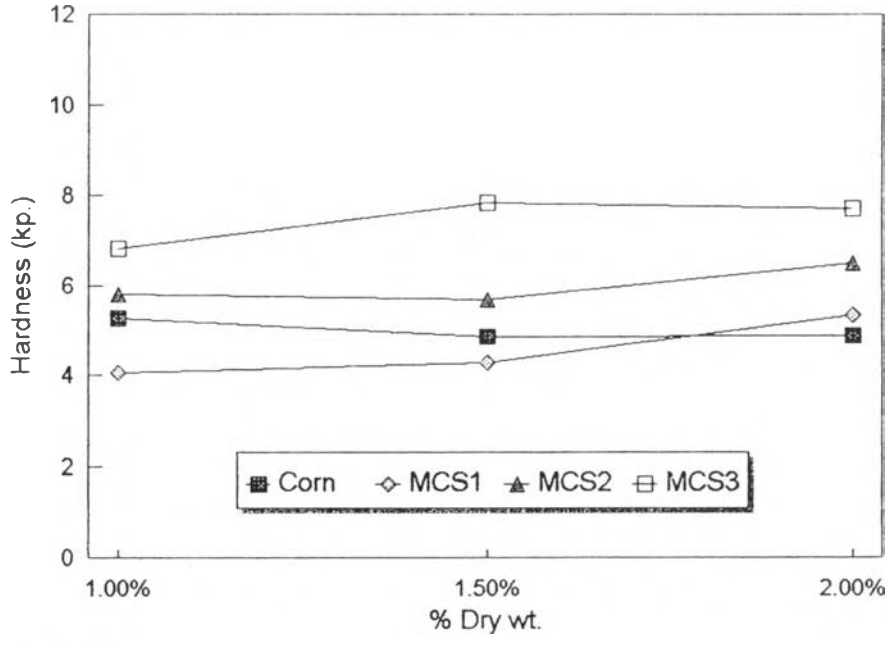

Figure **69** Hardness profiles of paracetamol tablets prepared with corn, MCS1, MCS2 or MCS3 at various concentrations by solution incorporation method.

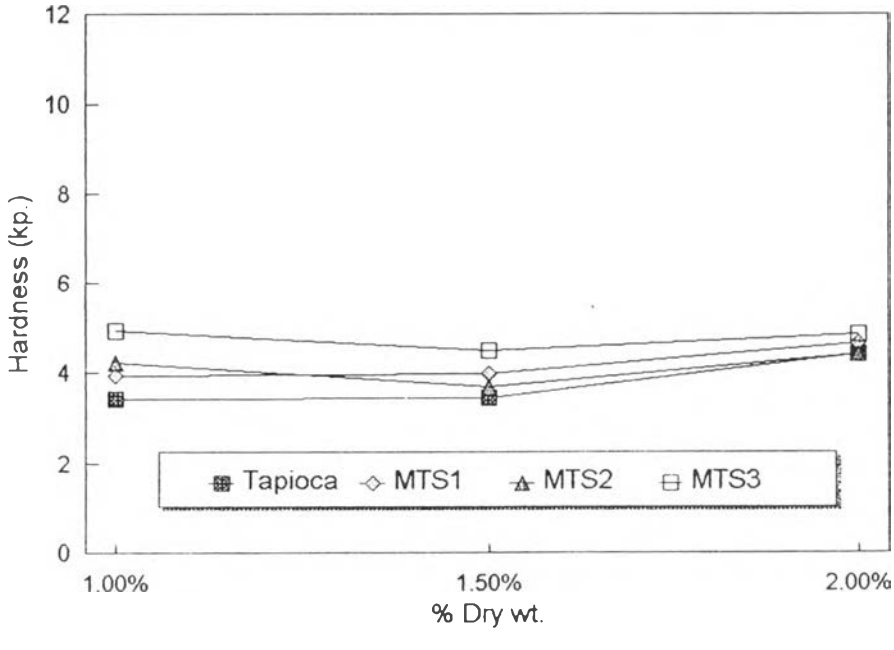

Figure **70** Hardness profiles of paracetamol tablets prepared with tapioca, MTS1, MTS2 or MTS3 at various concentrations by solution incorporation method.

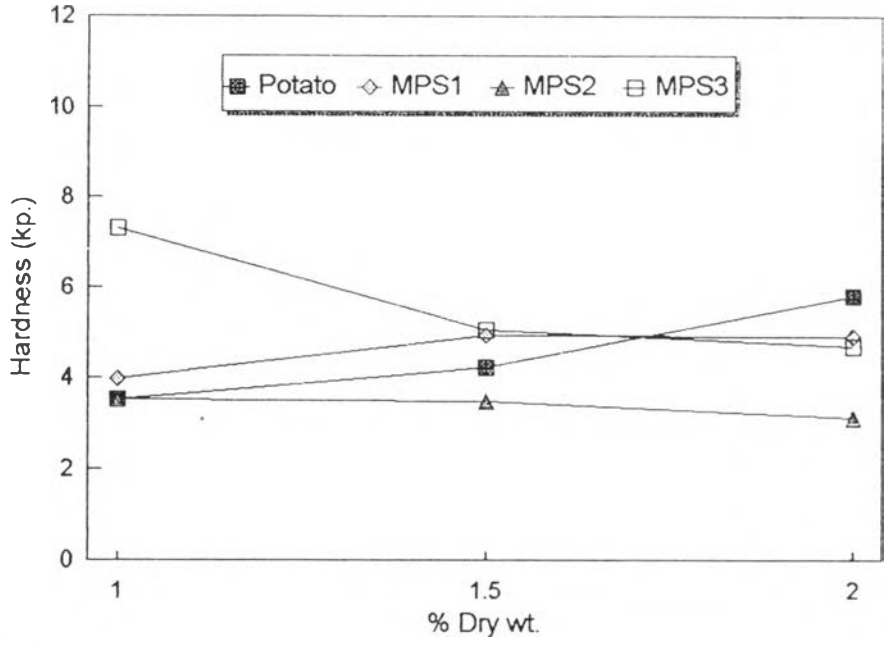

Figure **71** Hardness profiles of paracetamol tablets prepared with potato, MPS1, MPS2 or MPS3 at various concentrations by solution incorporation method.

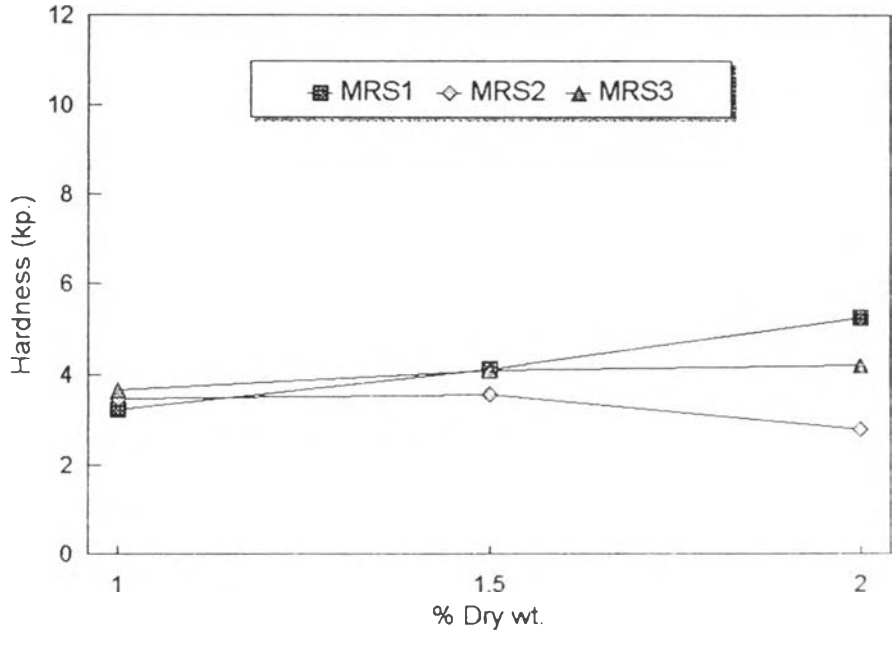

Figure **72** Hardness profiles of paracetamol tablets prepared with MRS1, MRS2 or MRS3 at various concentrations by dry incorporation method.

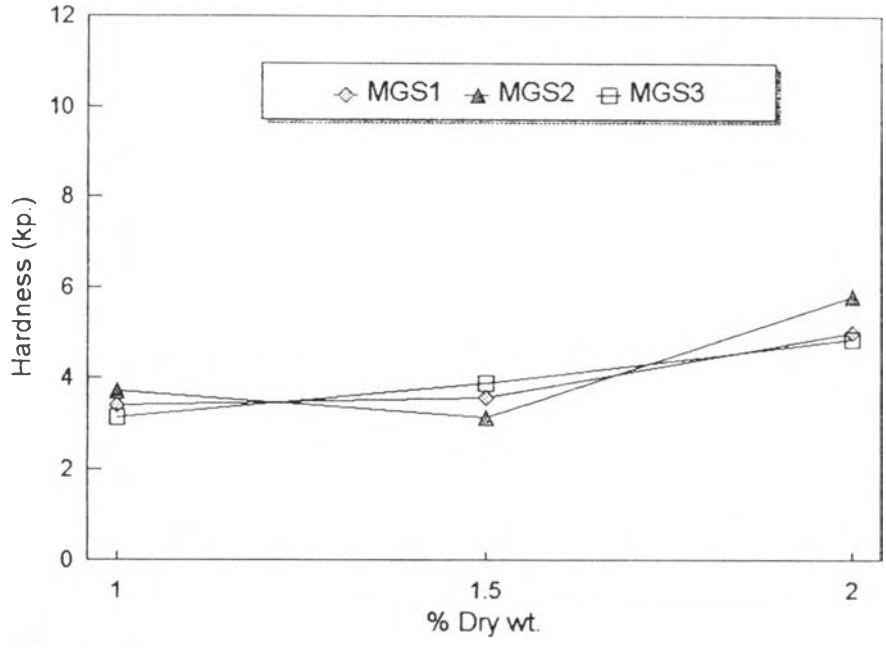

Figure **73** Hardness profiles of paracetamol tablets prepared with MGS1, MGS2 or MGS3 at various concentrations by dry incorporation method.

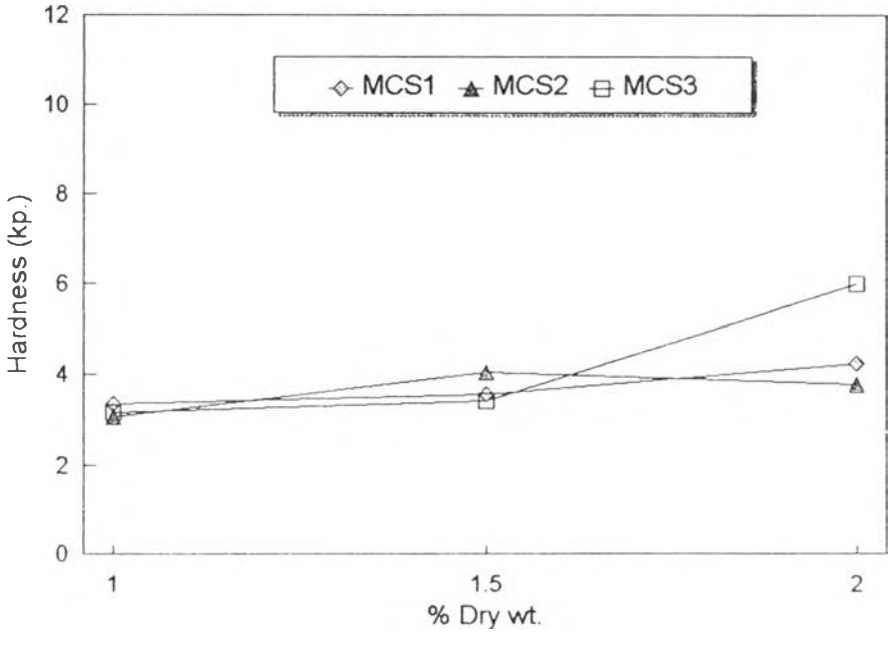

Figure **74** Hardness profiles of paracetamol tablets prepared with MCS1, MCS2 or MCS3 at various concentrations by dry incorporation method.

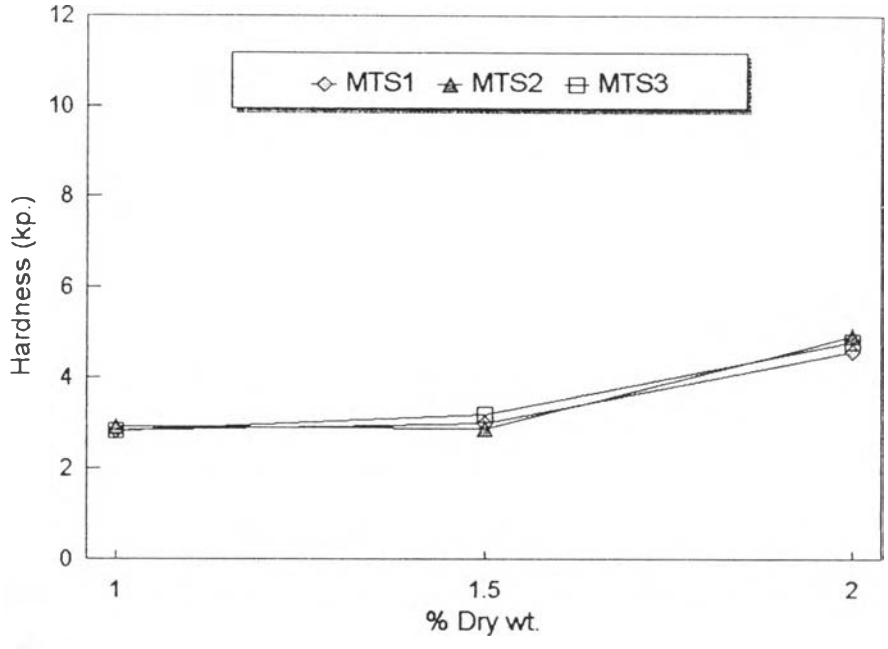

Figure **75** Hardness profiles of paracetamol tablets prepared with MTS1, MTS2 or MTS3 at various concentrations by dry incorporation method.

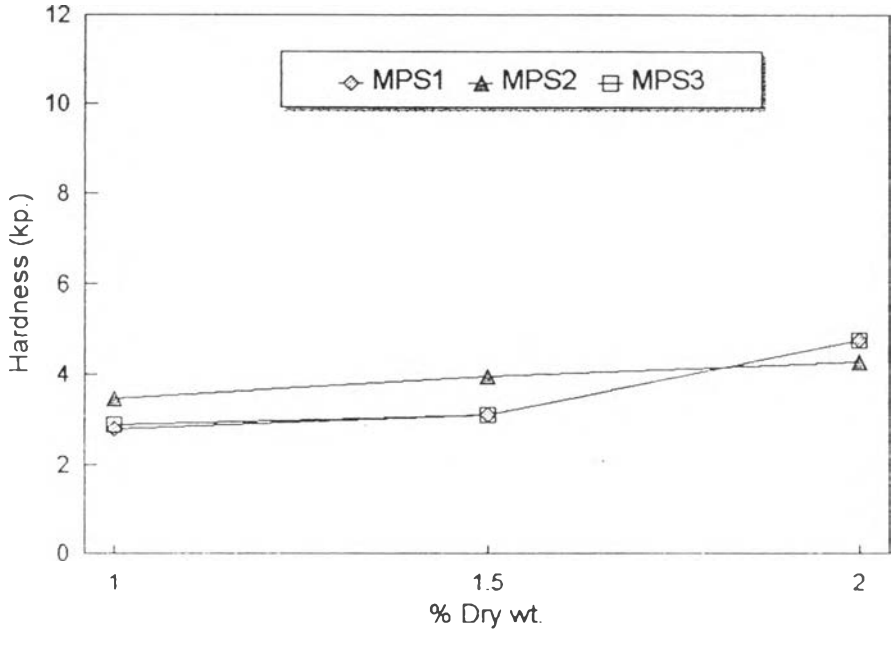

Figure **76** Hardness profiles of paracetamol tablets prepared with MPS1, MPS2 or MPS3 at various concentrations by dry incorporation method.

was MGS2 > MPS 3 > MCS3 ~ MRS3 > MGS1~ MCS2 ~ MRS1 ~ glutinous rice ~ corn > MRS2 ~ MTS3 > MGS3 ~ MTS2 ~ rice > MCS1 ~ MPS1 ~ MTS1 > potato ~ MPS2 ~ tapioca (see Tables 25 and 31 in Appencix D). At 1.5%, The rank ordered as follow : MGS2 ~ MCS3 > MRS3 > MGS3 ~ MRS1 ~ MCS2 > MGS1 ~ MPS3~ MPS1 ~ corn ~ MRS2 ~ MTS3 > glutinous rice ~ MCS1 ~ potato ~ MTS1 > MTS2 ~ rice ~ MPS2 ~ tapioca (see Tables 26 and 32 in Appendix D). At 2%, the rank was in the following order MGS3 > MGS2 > MCS3 ~ MRS1 > MCS2 ~ MRS3 > potato ~ MGS1 ~ MCS1 > MPS1 ~ corn ~ MTS3 ~ MRS2 ~ MPS3 ~ MTS1 ~ tapioca ~ MTS2 ~ rice > MPS2 ~ glutinous rice (see Tables 27 and 33 in Appendix D). By comparing among three levels of binder weight, The MGS3 at 2% binder weight gave the hardest tablet, then the MGS2 at 2% ,and the MGS2 at 1.5%. By dry incorporation method, the hardness of the tablets obtained by various types of the modified starches at the same weight was slightly different. Furthermore, the hardness of the tablets produced by this method was lower than which produced by solution incorporation method.

2.1.7. Tablet friability

Percent friability of tablets produced by wet and dry incorporation methods is shown in Tables 11 and 12 , respectively. The tablets using some modified starches were less friable than those using native starches. The dry incorporation method produced more friable granules in comparison with the solution incorporation method. Moreover, it was seen that the percent friability tended to decrease as the

Table **11** Percent friability of paracetamol tablets prepared with various binders and concentrations by solution incorporation method.

Binder	Percent friability of paracetamol tablets		
	1%	1.5%	2%
Rice	3.60	2.99	3.85
MRS1	2.14	1.59	1.18
MRS2	1.56	1.57	2.13
MRS3	1.95	1.20	1.35
Glutinous	2.88	1.79	2.31
MGS1	1.91	1.66	1.41
MGS2	2.58	1.88	1.80
MGS3	1.53	1.00	2.24
Corn	1.86	1.94	2.18
MCS1	4.37	4.17	3.44
MCS2	1.77	1.52	1.13
MCS3	1.12	1.07	0.79
Tapioca	4.17	3.86	3.40
MTS1	4.63	4.62	3.89
MTS2	3.99	3.70	3.32
MTS3	3.26	3.68	3.30
Potato	4.56	4.37	2.08
MPS1	3.75	3.22	3.59
MPS2	4.13	2.74	2.45
MPS3	2.45	1.91	1.53

Table **12** Percent friability of paracetamol tablets prepared with various binders and concentrations by dry incorporation method.

Binder	Percent friability of paracetamol tablets		
	1%	1.5%	2%
MRS1	4.54	3.55	3.62
MRS2	5.01	4.93	5.56
MRS3	5.60	4.55	2.73
MGS1	4.51	4.23	3.26
MGS2	5.60	4.77	3.00
MGS3	5.76	4.78	4.26
MCS1	5.59	5.36	3.34
MCS2	5.76	3.22	3.25
MCS3	5.76	3.78	2.11
MTS1	4.78	6.23	3.23
MTS2	5.92	4.63	2.87
MTS3	5.77	5.72	3.46
MPS1	5.54	4.07	3.51
MPS2	4.05	2.70	3.00
MPS3	5.99	5.01	3.14

amount of the binder increased. However it was not seen that the degree of substitution affected the percent friability.

2.1.8. Disintegration time

Disintegration time of tablets using various native or modified starches is shown in Figures 77-86 and Tables 37-38 (in Appendix D). By increasing the amount of a binder in the formulation prepared by wet and dry incorporation methods, a progressive increase in disintegration time was observed. With solution incorporation method, the disintegration time of the tablets using 1% binder weight was ranging as follow rice ~ tapioca ~ potato ~ corn ~ glutinous rice ~ MRS2 < MCS1 ~ MCS2 ~ MTS2 ~ MTS3 ~ MGS2 < MRS1 ~ MCS3 ~ MPS3 ~ MGS3 < MGS1 ~ MRS3 ~ MTS1 < MPS2 < MPS1 (see Tables 39 and 45 in Appendix D). At 1.5%, the rank was in the following order : tapioca ~ rice ~ potato ~ corn ~ glutinous rice ~ MRS2 < MCS1 ~ MTS2 < MCS3 ~ MGS2 ~ MCS2 ~ MTS3 ~ MPS3 < MTS1 ~ MRS3 ~ MRS1 < MGS3 < MGS1 < MPS1 ~ MPS2 (see Tables 40 and 46 in Appendix D). At 2%, The rank ordered as follow rice ~ tapioca ~ corn ~ potato ~ glutinous rice < MGS2 ~ MRS2 < MTS2 < MCS1 ~ MPS3 ~ MGS1 ~ MRS3 ~ MCS2 ~ MTS3 ~ MCS3 < MGS3 ~ MTS1 ~ MRS1 < MPS1 < MPS2 (see Tables 41 and 47 in Appendix D). Comparison of the two addition methods, using modified starch as a binder, the tablets produced by solution incorporation method exhibited longer disintegration time, except at 2% binder weight.

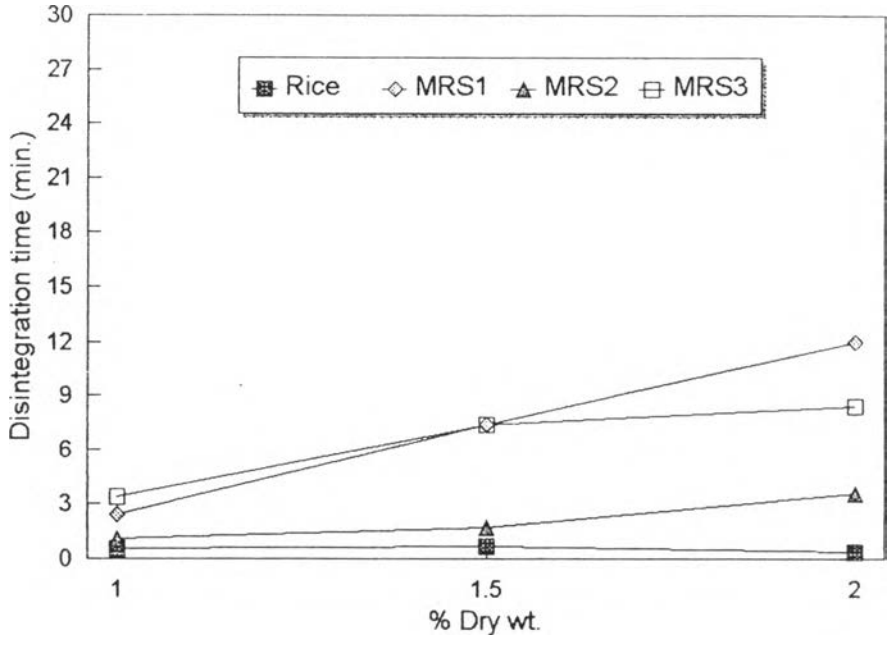

Figure **77** Disintegration time profiles of paracetamol tablets prepared with rice, MRS1, MRS2 or MRS3 at various concentrations by solution incorporation method.

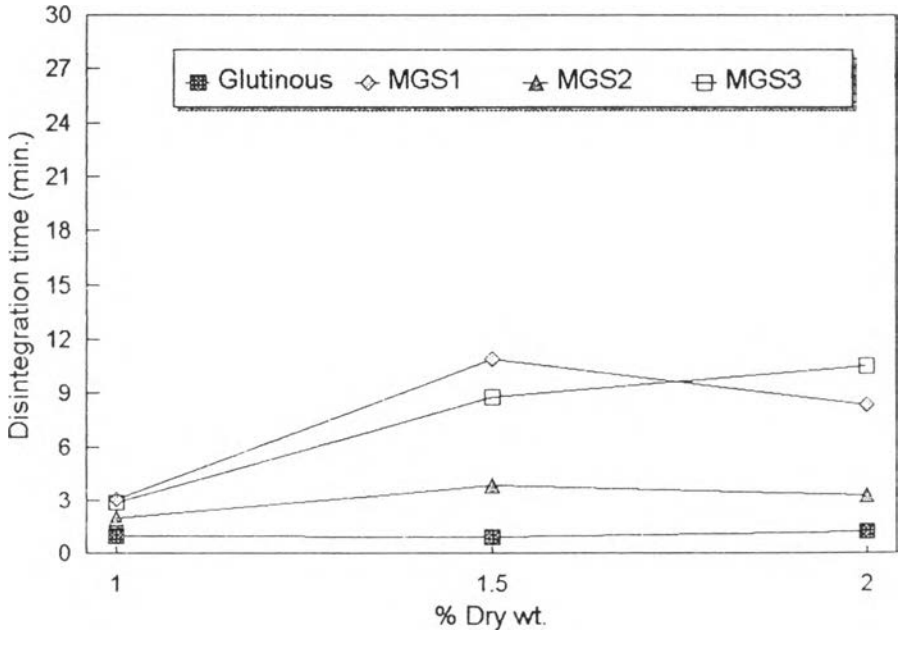

Figure **78** Disintegration time profiles of paracetamol tablets prepared with glutinous rice, MGS1, MGS2 or MGS3 at various concentrations by solution incorporation method.

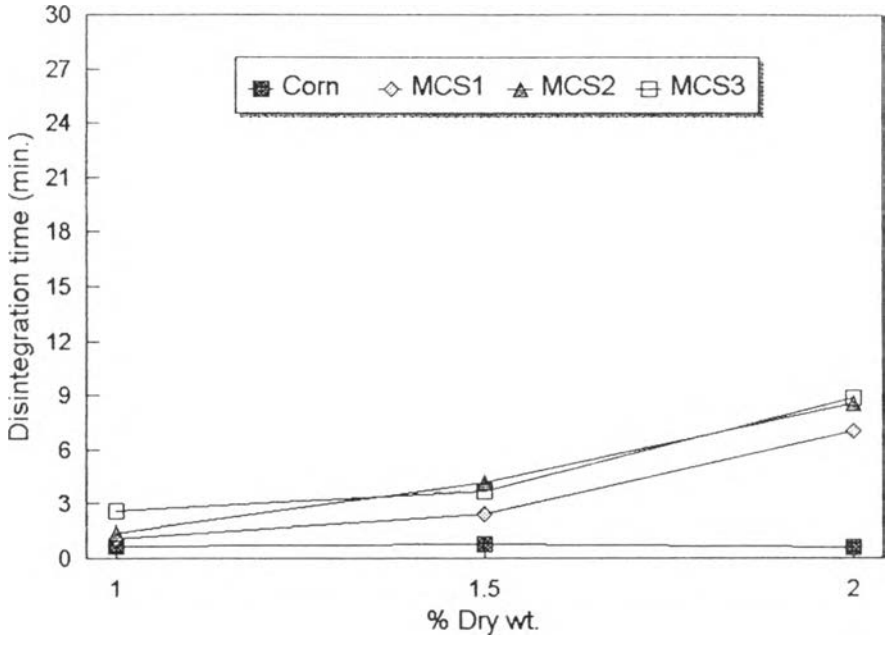

Figure **79** Disintegration time profiles of paracetamol tablets prepared with corn, MCS1, MCS2 or MCS3 at various concentrations by solution incorporation method.

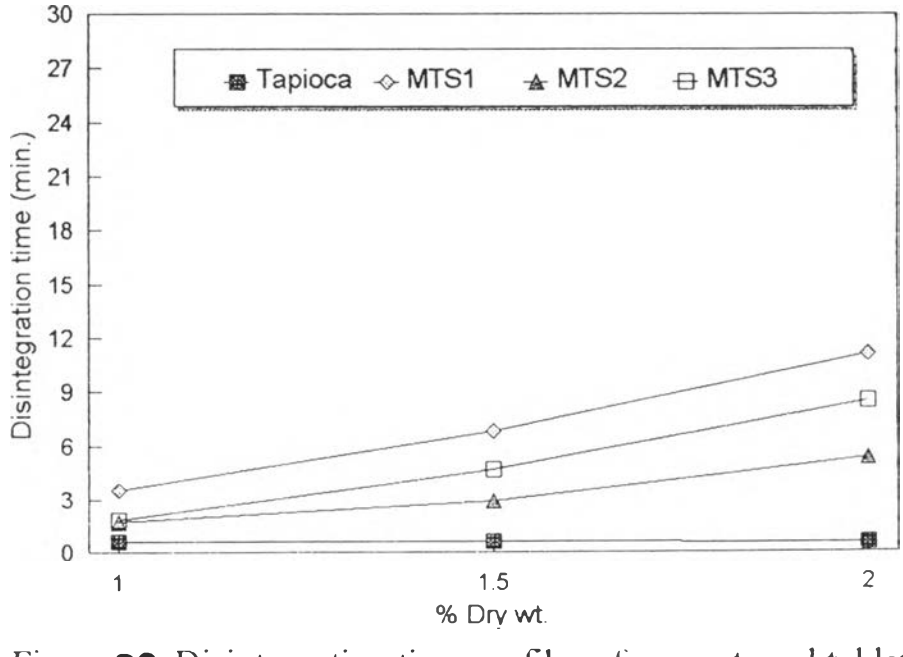

Figure **80** Disintegration time profiles of paracetamol tablets prepared with tapioca, MTS1, MTS2 or MTS3 at various concentrations by solution incorporation method.

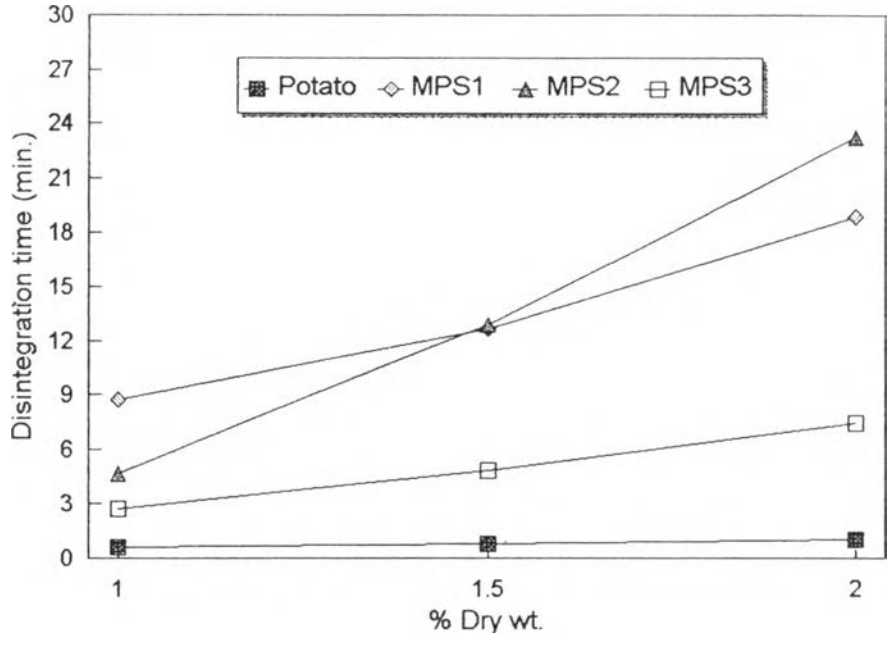

Figure **81** Disintegration time profiles of paracetamol tablets prepared with potato, MPS1, MPS2 or MPS3 at various concentrations by solution incorporation method.

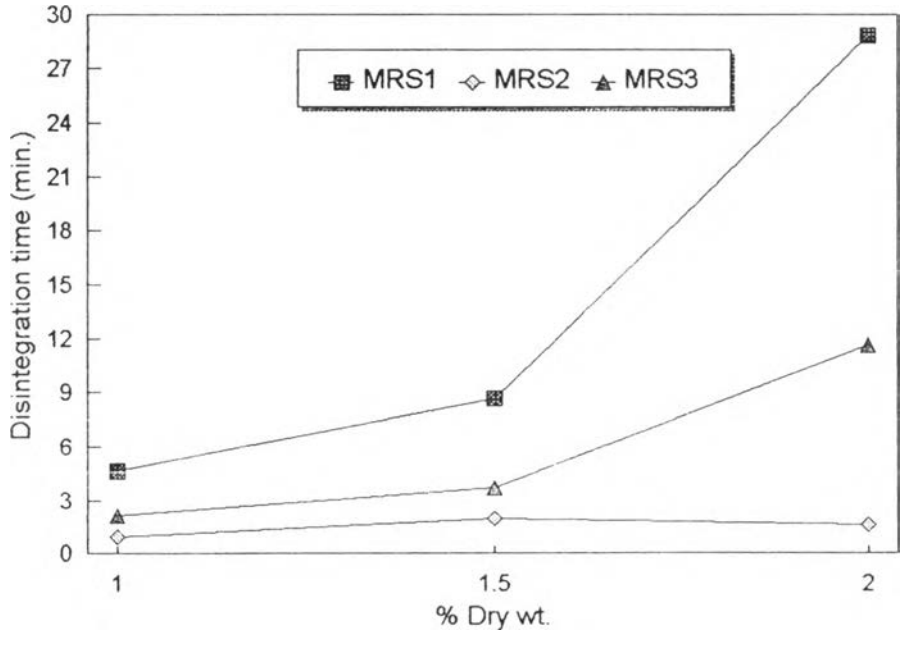

Figure **82** Disintegration time profiles of paracetamol tablets prepared with MRS1, MRS2 or MRS3 at various concentrations by dry incorporation method.

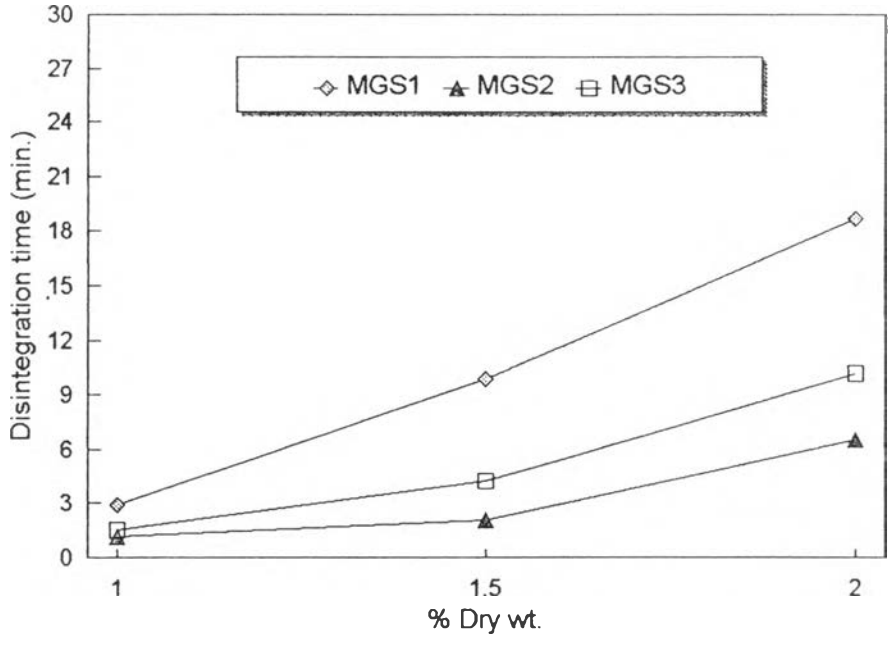

Figure **83** Disintegration time profiles of paracetamol tablets prepared with MGS1, MGS2 or MGS3 at various concentrations by dry incorporation method.

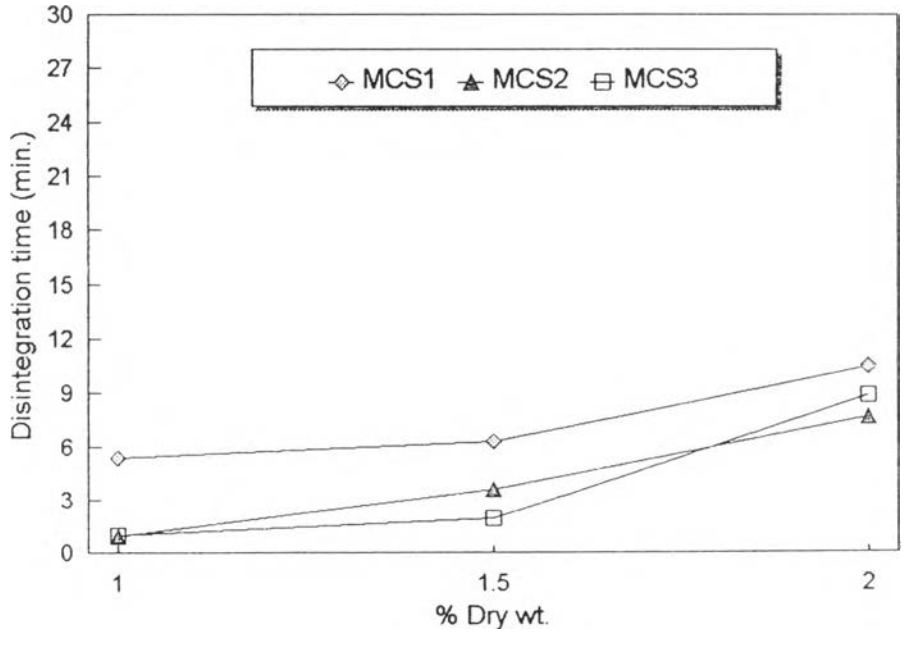

Figure **84** Disintegration time profiles of paracetamol tablets prepared with MCS1, MCS2 or MCS3 at various concentrations by dry incorporation method.

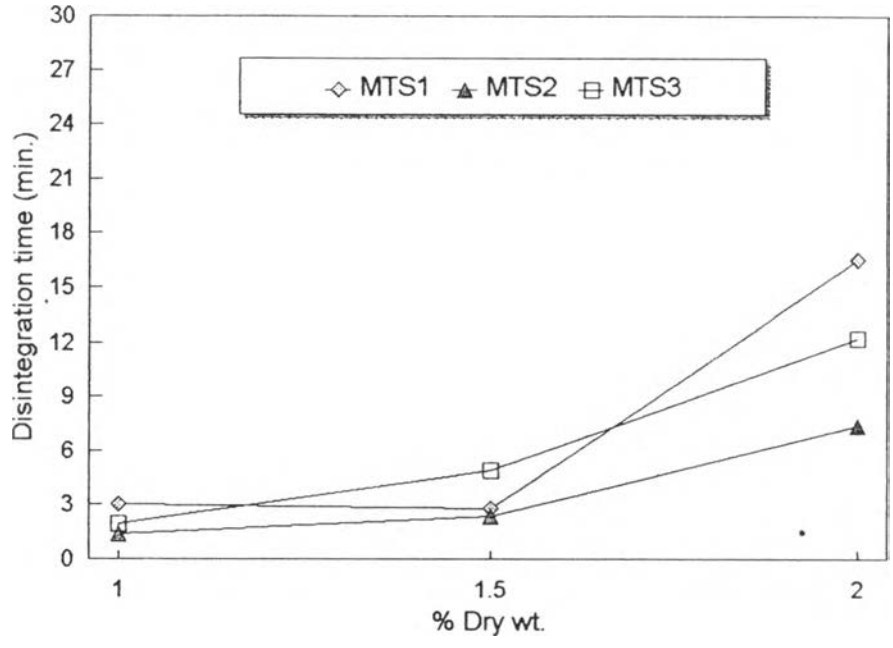

Figure **85** Disintegration time profiles of paracetamol tablets prepared with MTS1, MTS2 or MTS3 at various concentrations by dry incorporation method.

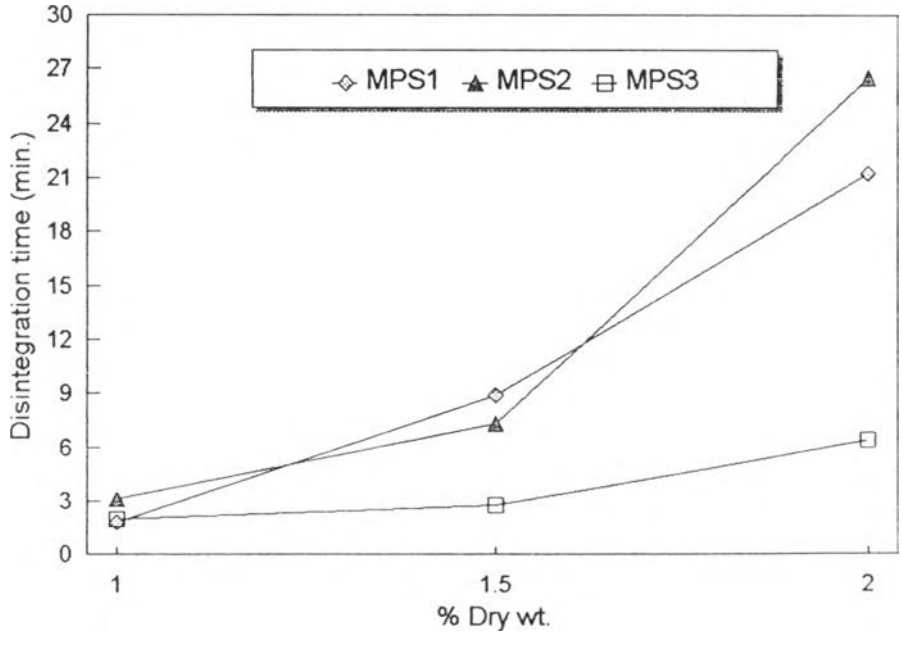

Figure **86** Disintegration time profiles of paracetamol tablets prepared with MPS1, MPS2 or MPS3 at various concentrations by dry incorporation method.

2.2. Selection of the formulation which exhibited good physical properties.

From 2.1, MGS2 as the paste form was the best binder. It imparted the hardest tablets with the shortest disintegration time. So, MGS2 was chosen to compare with PVP K30 and Era-Gel^R for further studies.

2.3. Comparison of the formulation containing MGS2 with the formulations containing PVP K30 and Era-Gel^R.

2.3.1. Particle size distribution

The size distribution of the granules using MGS2, PVP K30 and Era-Gel^R as binders at 1, 1.5 and 2% binder weight are depicted in Figures 87-89. As can be seen from the Figures, PVP K30 produced narrower distribution than MGS2 and Era-Gel^R did. Figure 90 shows D_{50} of paracetamol granules containing MGS2, PVP K30 and Era-Gel^R . In general, it might be concluded that, the size of MGS2 granules and Era-Gel^R granules were similar and they were smaller than of PVP K30 granules.

2.3.2 Bulk density, tapped density and percent compressibility

The bulk density, tapped density and % compressibility are tabulated in Table 13. It was seen that the granules using Era-Gel^R exhibited the lowest bulk density and the highest % compressibility.

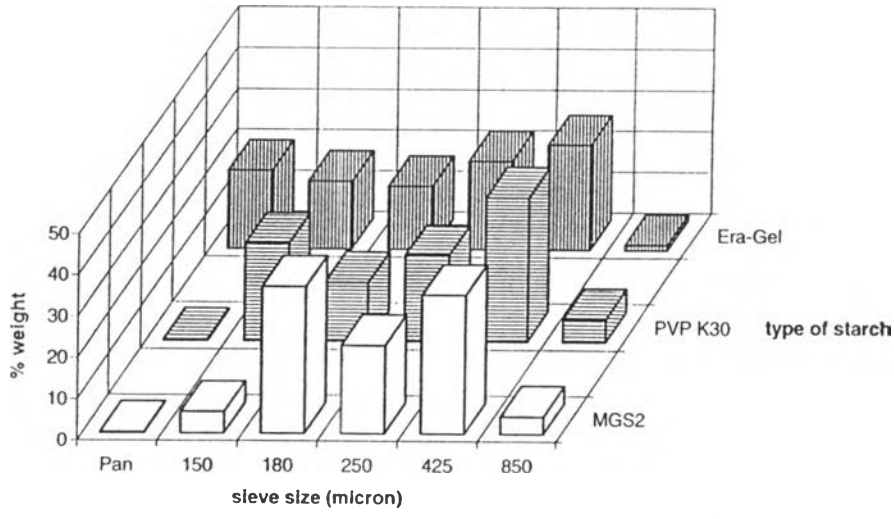

Figure **87** Histograms for particle size distribution of paracetamol granules prepared with MGS2, PVP K30 and Era-Gel^{R} at 1% dry weight by solution incorporation method

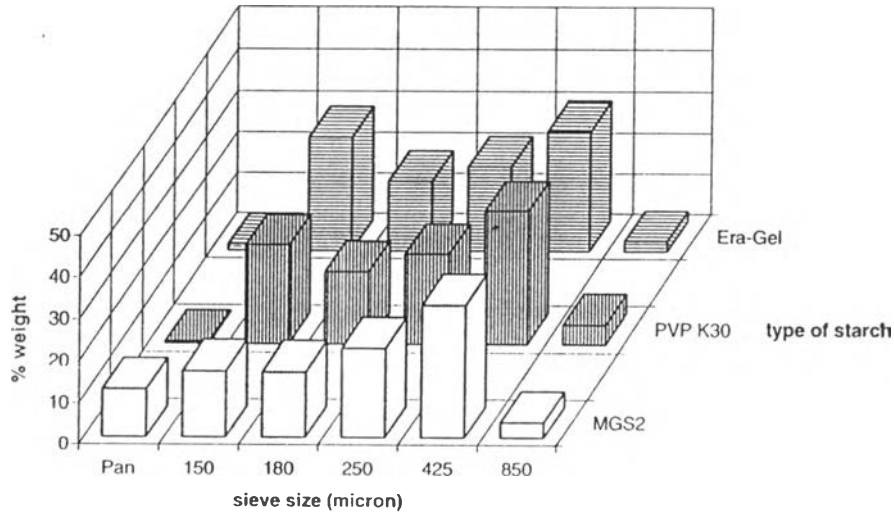

Figure **88** Histograms for particle size distribution of paracetamol granules prepared with MGS2, PVP K30 and Era-Gel^{R} at 1.5% dry weight by solution incorporation method

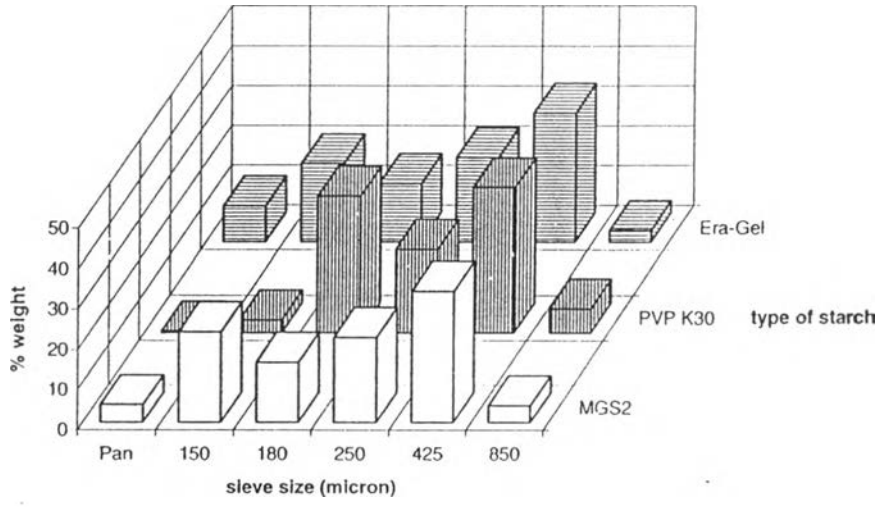

Figure **89** Histograms for particle size distribution of paracetamol granules prepared with MGS2, PVP K30 and Era-Gel^{R} at 2% dry weight by solution incorporation method

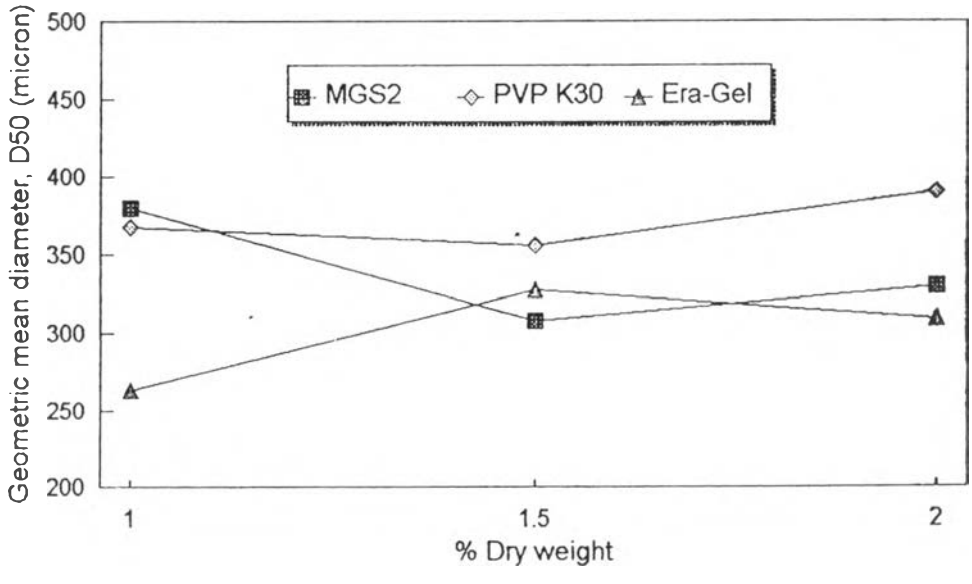

Figure **90** Geometric Mean Diameter (D50) of paracetamol granules prepared with MGS2, PVP K30, and Era-Gel at 1, 1.5 and 2% dry weight by solution incorporation method.

Table **13** Bulk density, tapped density and percent compressibility of paracetamol granules prepared with MGS2, PVP K30 or Era-Gel^{R} at various concentrations by solution incorporation method.

Binder	Physical properties of paracetamol granules								
	Bulk density (gm/ml)			Tapped density (gm/ml)			% Compressibility		
	1%	1.5%	2%	1%	1.5%	2%	1%	1.5%	2%
MGS2	0.41	0.41	0.41	0.60	0.60	0.60	31.98+0.61	32.12+0.29	32.12+0.29
PVP K30	0.40	0.40	0.40	0.58	0.58	0.59	30.44+0.15	30.58+0.02	32.00+0.00
Era-Gel^{R}	0.37	0.36	0.36	0.60	0.60	0.60	37.35+0.07	37.20+0.63	40.00+0.00

2.3.3. Flow rate and angle of repose

The flow rate and angle of repose of the granules containing MGS2, PVP K30 and Era-Gel^{R} are depicted in Table 14. All exhibited good flow properties.

2.3.4. Percent friability

Granulation friability was chosen as a measure of granulation quality. Figure 91 displays percent friability of the MGS2, PVP K30 and Era-Gel^{R} granules at various binder contents. It was noted that as the formula weight of the binders increased, the friability decreased. The Era-Gel^{R} yielded the most friable granulation and the PVP K30 yielded the strongest granulation. However at 1.5 and 2% of binder, MGS2 produced the granule strength in the same degree of PVP K30.

2.3.5. Tablet thickness

The thickness of the tablets containing MGS2, PVP K30 or Era-Gel^{R} were shown in Table 15. It was revealed that the tablets using MGS2 showed the least thickness, then PVP K30, and then Era-Gel^{R} .

Table **14** Flow rate and angle of repose of paracetamol granules prepared with MGS2, PVP K30 or Era-Gel^{R} at various concentrations by solution incorporation method

Binder	Flow rate (gm./ min)			Angle of repose		
	1%	1.5%	2%	1%	1.5%	2%
MGS2	231.92±7.57	195.52±2.02	218.63±1.52	36.25±0.00	37.01±0.44	34.58±0.51
PVP K30	180.71±3.60	198.55±2.51	204.33±12.87	37.77±1.34	36.87±0.00	34.66±2.50
Era-Gel^{R}	184.14±2.70	214.34±4.47	198.36±16.18	38.38±0.78	36.43±1.18	35.16±0.87

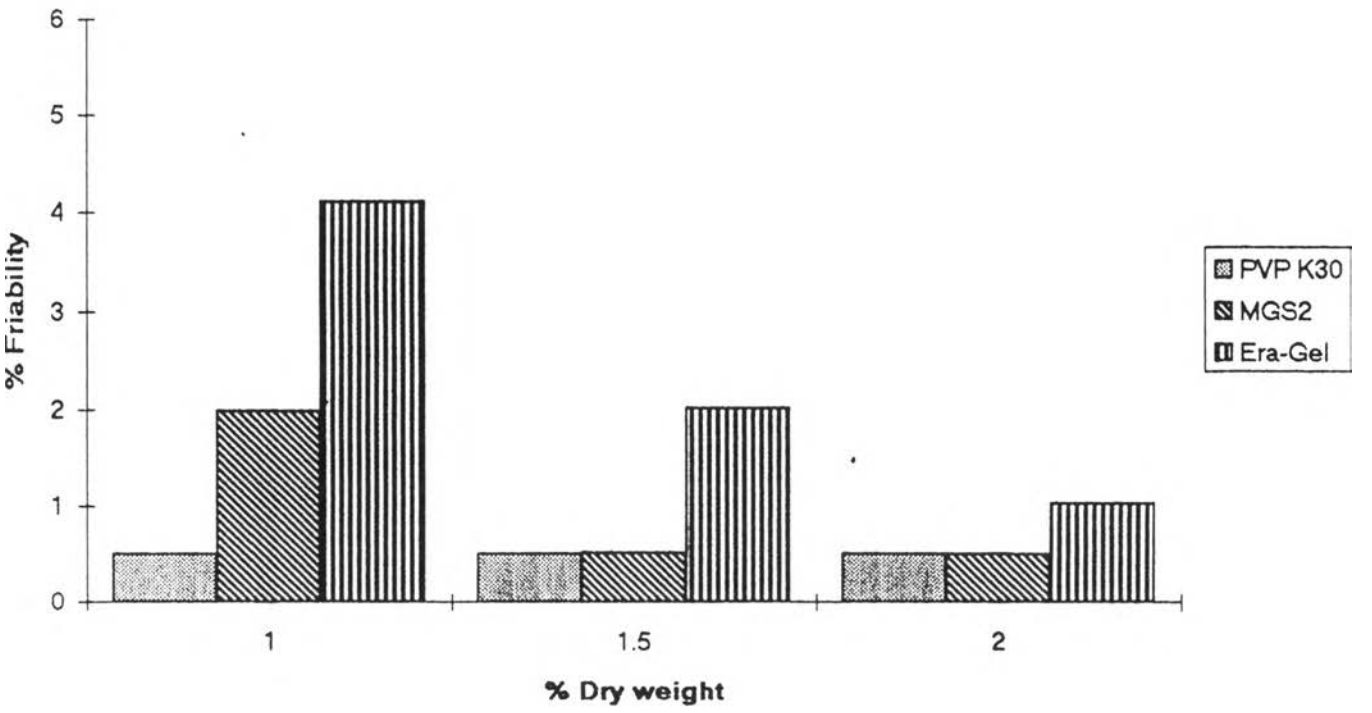

Figure **91** Histograms for the percent friability of paracetamol granules prepared with MGS2, PVP K30 or Era-Gel^{R} at various concentrations by solution incorporation method.

Table **15** Thickness of paracetamol tablets using MGS2, PVP K30 or Era-Gel^{R} at 1, 1.5 and 2% dry weight by solution incorporation method.

Binder	Thickness of paracetamol tablets (mm.)		
	1%	1.5%	2%
MGS2	4.009(0.007)*	4.018(0.010)*	3.991(0.018)*
PVP K30	4.075(0.011)	4.106(0.013)	4.120(0.012)
Era-Gel^{R}	4.152(0.016)	4.167(0.015)	4.159(0.011)

2.3.6. Tablet hardness

The hardness profiles of paracetamol tablets prepared with the MGS2, PVP K30 and Era-Gel^R are shown in Figure 92. The tablets containing MGS2 was harder than which containing Era-Gel^R at any binder weight (see Tables 51-56 in Appendix D). At 1.5 and 2% level, the MGS2 yielded the tablets as strong as the PVP K30 did (see Tables 52-53 and 55-56 in Appendix D). The tablets containing MGS2 or PVP K30 were harder than the others containing Era-Gel^R at any formular weight of binder. The hardness was significantly increased with the increasing of the weight of MGS2 and Era-Gel^R in the formulation.

2.3.7. Tablet friability

Figure 93 shows the friability of paracetamol tablets prepared with MGS2, PVP K30 and Era-Gel^R at various concentrations in final formula. From the Figure, the PVP K30 produced the least friable tablets and the Era-Gel^R produced the most friable tablets. The degree of friability decreased as the binder content increased except, the tablets using PVP K30, the friability of them were similar at all concentrations of the binder.

2.2.8 Disintegration time

Figure 94 exhibits the disintegration time profiles of paracetamol tablets containing MGS2, PVP K30 and Era-Gel^R. The

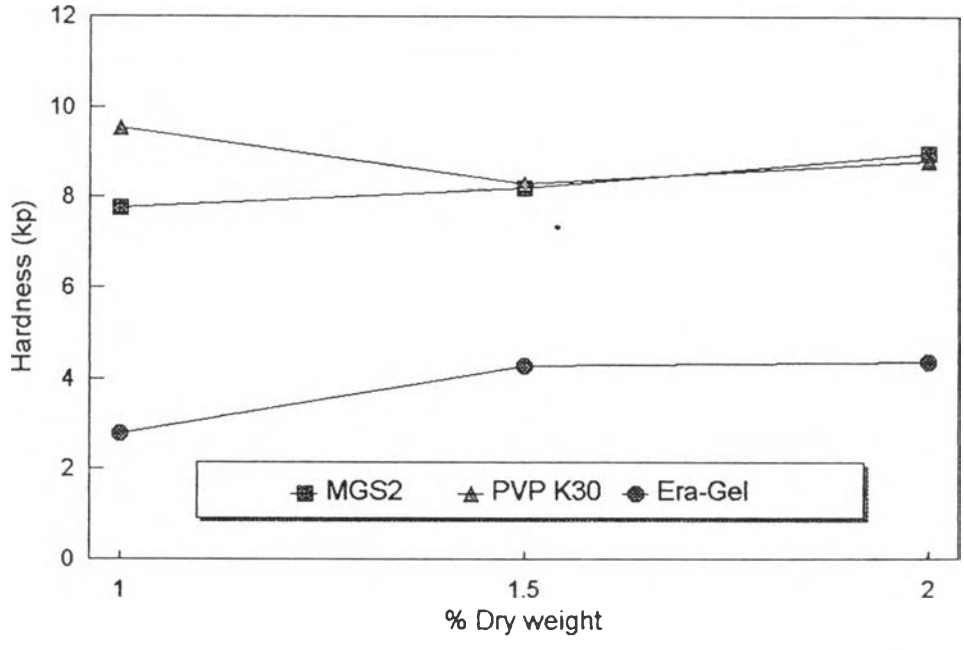

Figure **92** Hardness profiles of paracetamol tablets prepared with MGS2, PVP K30 and Era-Gel at 1,1.5 and 2% dry weight by solution incorporation method.

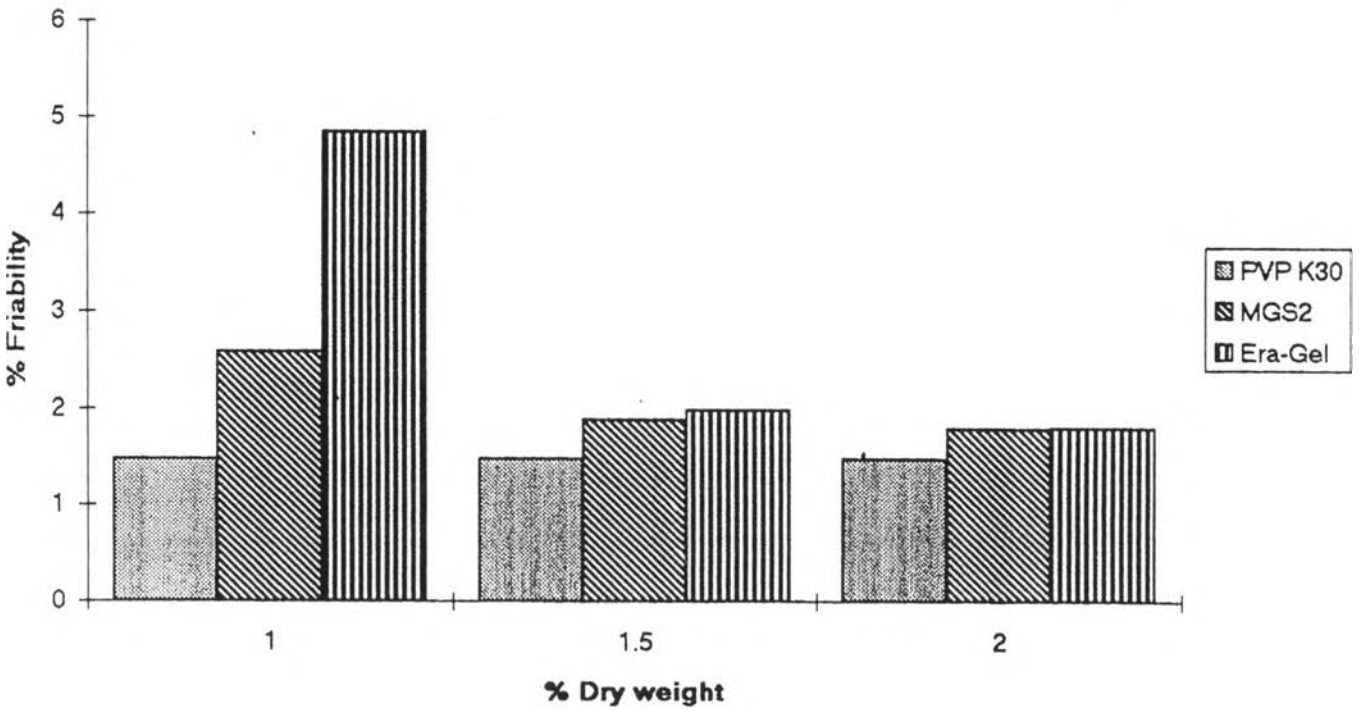

Figure **93** Histograms for the percent friability of paracetamol tablets prepared with MGS2, PVP K30 or Era-Gel^{R} at various concentrations by solution incorporation method.

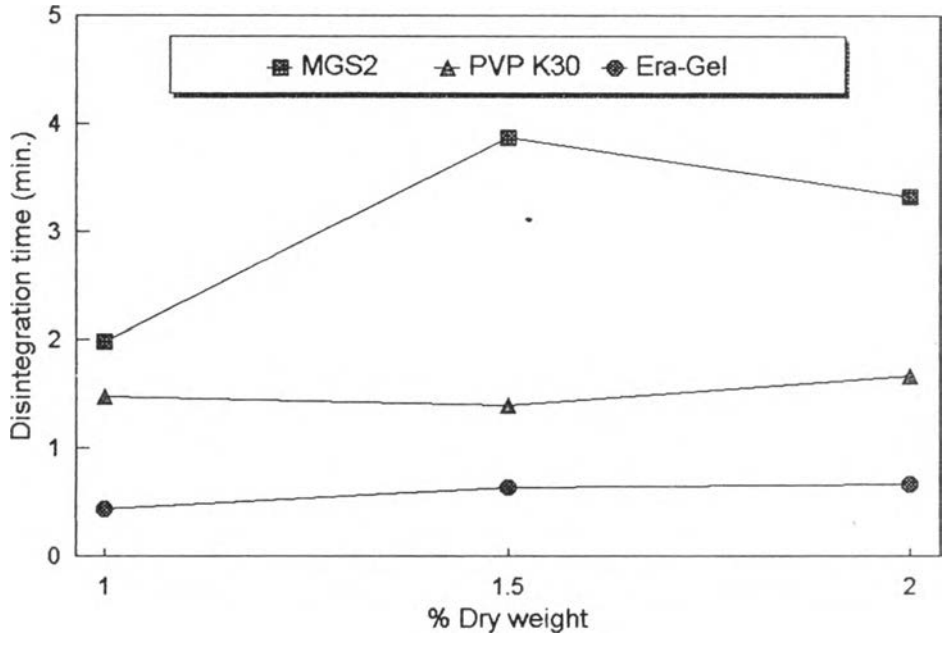

Figure **94** Disintegration time profiles of paracetamol tablets prepared with MGS2, PVP K30 and Era-gel at 1,1.5 and 2% dry weight by solution incorporation method.

MGS2, PVP K30 and Era-Gel^{R} gave the tablets disintegrating in a few minutes. The disintegration time of these tablets was not more than 4 minutes. The rank of the disintegration time at any level of binder weight was Era-Gel^{R} < PVP K30 < MGS2 (see Tables 57-62 in Appendix D). The disintegration time was longer as the binder weight increased.

2.3.9. Dissolution time

Only the tablets containing MGS2 and PVP K30 at 2% dry binder were tested for the dissolution time which was performed in accordance with USP XXII and the profiles are shown in Figure 95. It was noted that the percent dissolved of both formula met the requirement of USP XXII that the quantities of dissolved paracetamol were not less than 80% of the labled amount within 30 minutes. The dissolution rate of the tablets using MGS2 was slower than of the tablets using PVP K30 in the early stages of dissolution but they exhibited complete dissolution within 20 minutes.

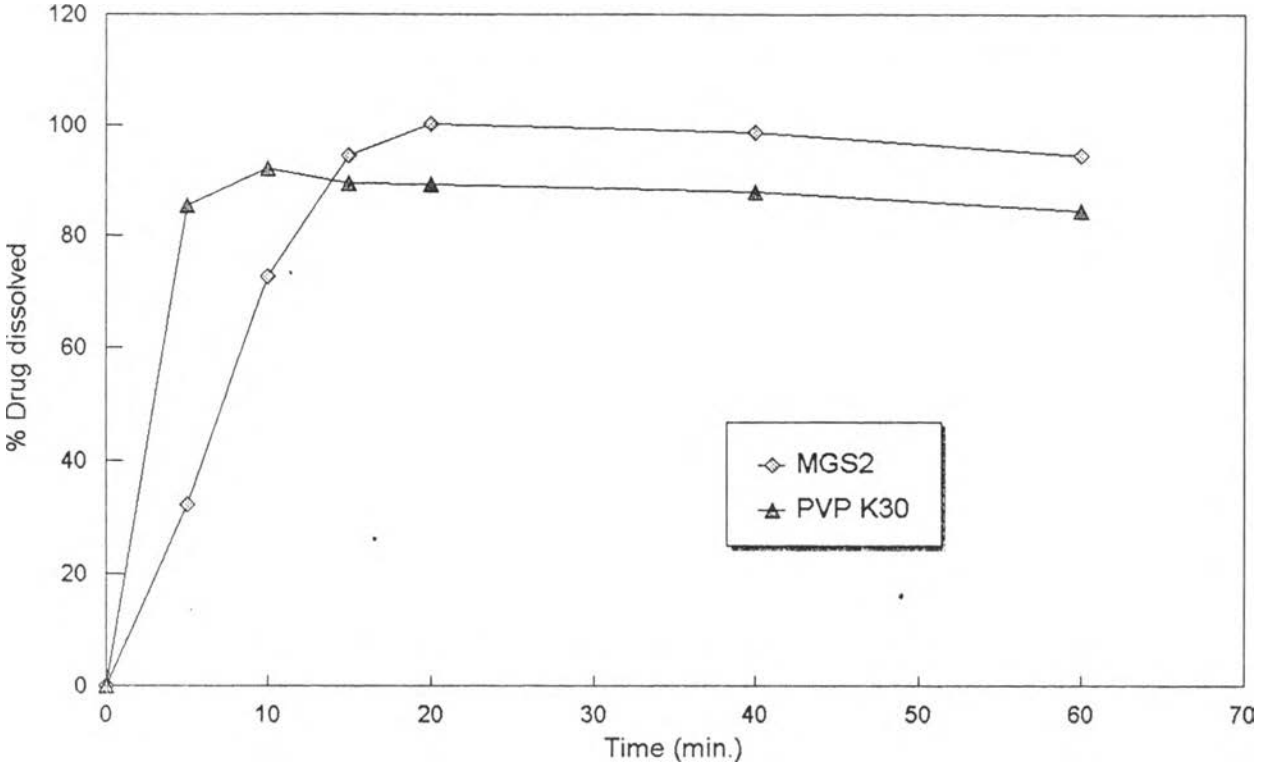

Figure **95** Dissolution rate profiles of paracetamol tablets prepared with MGS2 and PVP K30 at 2% dry weight by solution incorporation method.