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Prediction of Firmness and Strength of Low-ester Pectin Gel from Chemical Composition

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Abstract

High-ester pectin was demethylated by the treatments of HCl alone and a combination of HCl and NH_4OH. The low-ester pectin prepared were analyzed for chemical composition and the pectin gels were evaluated for firmness by sag values and strength by puncture stress. Gels made from HCl demethylated sample showed brittle, weak and poor elastic characteristics while the HCl-NH_4OH treated samples generally resulted in a smooth and elastic gels except those samples having very low content of ester group or acid amide group. Statistical analysis showed that significant correlations were found between sag values and ester content or molecular weight, and puncture stress and ester content, acid amide groups or molecular weight. The equations derived for sag, puncture stress and sag/puncture stress from chemical data could be useful for prediction of some of the physical properties of low-ester pectin gel.

Introduction

Low-ester or low-methoxyl pectin, which has an ability to form gels with or without sugar addition in the presence of divalent cations, has been extensively investigated for its physicochemical gel properties and methods for preparation. Gels made from low-ester pectin are reported to be relatively stable at room temperature[1] and they retain their shape at high temperature better than gelatin gels.[2] Although low-ester pectins can be obtained either by extraction from some of the plants such as sunflower heads[3,4] or by demethylation of high-ester pectin, commercial low-ester pectins are generally produced by demethylation of high-ester pectin. The demethylation process was classified by (1) acid, (2) alkali, (3) enzyme and (4) ammonia in alcohol according to the agents used.[5] The fourth method with ammonia is differed from other methods by yielding amide groups on carbon No. 6 in addition to carboxyl and methoxyl groups.

Many workers have studied on gelling characteristics of low-ester pectins as affected by conditions used for gel preparation such as pH, calcium and pectin concentrations,[6,7,8] and the methoxyl content of the pectin.[9,10] Fectors involved in the chemical nature affecting on gel characteristics include the degree of esterification, the contents of amide and acetyl groups and molecular weights which are varied by methods of demethylation.[9,11] Kim *et al.*[12] reported that higher concentration of acid or ammonia at low temperature resulted in less depolymerization and more conversion of methoxyl group to acid amide groups as their changes compared to the rate of deesterification. They[11] also studied the effect of the chemical composition on the compressive rheological properties of low-ester pectin gel and found the significant correlations between them. Eventhough sag and puncture point, the empirical textural properties for measurement of firmness and strength of pectin gel, have been studied with some of the chemical nature of low-ester pectin, statistical approach to predict them from the chemical composition are not yet reported in literature.

The objective of this research was to study the correlation between the chemical composition of low-ester pectin and firmness and strength of gel characteristics so that the textural properties can be predicted by regression equation.

Material and Methods

Materials

All of the high-ester pectins used for low-ester pectin preparation were supplied by Sunkist Growers. Inc. (Ontario, California). The pectins were extracted from

Citrus peel with Sodium bisulfite solution, filtered, precipitated with aluminum hydroxide, pressed and dried. The high-ester pectin had 63.3% esterification and an apparent molecular weight of 146.69×10^3.

Preparation of low-ester pectin

Low-ester pectins were prepared by two demethylation methods of acid alone and combination of acia and ammonia. For acid treatment, high ester pectin was demethylated with 4.5N HCl at 3°C for various time periods. The acid-ammonia demethylated samples were prepared by a first step demethylation using 4.5N HCl at 3°C, followed by a second step demethylation using NH_4OH in alcohol at different temperature. The detailed method for preparation of low-ester pectin was followed by the procedure described by Kim *et al.*[10]

Chemical analysis

The chemical properties of degree of esterification, galacturonic acid, acid amide groups and free carboxyl groups and apparent molecular weight of pectin were measured for the low-ester pectin prepared. The moisture content of samples were determined by drying at 105°C for 2 hours.[11]

Percent of esterification refers to the number carbon No. 6 methylated per 100 carboxyl groups and was calculated from methoxyl content (weight basis) which was determined by the procedures described in the National Formulary.[14]

An accurately weighted 0.35*g* of sample was placed in a 250*ml* Erlenmeyer flask and wetted with 1*ml* ethanol. One hundred milliliters of distilled water were then added and the flask was shaken to dissove the pectin. The solution was titrated with 0.5*N* NaOH to a phenolphthalein endpoint. This result was recorded as the initial titration. After the initial titration, 20 *ml* 0.5 *N* NaOH were added and shaken occasionally for 15 minutes. A 20*ml* of 0.5*N* HCl were then added and the flask shaken until the pink color disappeared. The solution was then titrated with 0.5*N* NaOH to a phenolphthalein endpoint (saponification titration). Since each *ml* 0.5*N* NaOH used during saponification is equivalent to 15.52 *mg* methoxyl[8] the percent methoxyl can be calculated as follows:

$$\%OCH_3 = \frac{ml\ \text{NaOH used in saponification titration} \times 0.01552}{\text{weight pectin (moisture and ash free)}} \times 100$$

$$\%\ \text{Esterification} = \frac{\%\ \text{methoxyl group}}{16.32} \times 100$$

where 16.32% corresponds to saturation of all the carboxyl groups with methoxyl group on carbon No. 6 in pectin.

For measurement of amide content, the procedure used by Black and Smit[8] was modified for nitrogen determination by micro-kjeldahl method and percent and amide groups in pectin was calculated by the formula of Kim *et al.*[4]

Free carboxyl groups were calculated by substracting percents esterification and acid amide groups from 100, and the apparent molecular weight by viscosity was measured and calculated by the procedure described by Kim *et al.*[11]

Gel preparation

The procedure for preparation of low-ester pectin gels was essentially the same as that described by Black and Smit[8] and Kim *et al.*[11] except for a modification of the gel weight and the gel container. The pH of the gels was kept at 3.8 ± 0.5.

Gel, after cooking to the desired weight, were poured into plexiglas cylinders (50 *mm* height and 44 *mm* ID) for sag measurement and puncture test. The top portion of the cylinder was wrapped with masking tape to extend about 1/4 inch above the edge. The bottom cylinder was attached to a sheet of plastic wrap and then supported a glass plate. The gels were then stored at 4°C overnight.

Sag measurement

After storage at 4°C, the excess gel above the top edge was removed with using a thin spatula and, the removed gel was allowed to stand straight height on a supporting plate for one minute. And then its sag was measured with the Sunkist Exchange Ridgelimeter (Sunkist Growers. Inc., California). The reading on the ridgelimeter were converted to actual gel sag in *mm*.

$$\text{Sag in } mm = (B\text{-}A) \times 0.8$$

where A = Ridgelimeter reading of empty cylinder and B = Ridgelimeter reading of the gel.

Puncture test

Immediately after sag reading was taken the gel was cut crosswise by 15*mm* thickness and the slices were

kept at 10°C until tested. A plunger (11.151 *mm* diameter) was adapted into compression cell of Instron universal testing machine Model 1130 (Instron Corp., Mass.) and the failure point in force and time curve was measured with a crosshead speed of 2 inches per minute. The puncture stress at failure point was calculated in Newton per cm^2.

$$\text{Puncture stress, } N/cm^2 = \frac{\text{Puncture force in Newton}}{\text{Cross-sectional area of gel}}$$

Statistical analysis

Three replications for sag measurement and nine replications for puncture test were made for each low-ester pectin prepared. From the results, correlation coefficients between each of chemical and physical properties were calculated. Using chemical values and molecular weight as independent variables and physical properties as dependent variables, equations were obtained using a linear regression procedure and a sequential F-test[15].

$$Y = \alpha + \beta_1 \cdot X_1 + \beta_2 \cdot X_2 + \cdots\cdots + \beta r \cdot X r$$

Where Y = dependent variable, X's = independant variables which were significantly correlated to the physical properties by 10% level or less, ß = regression coefficient and α = intercept. As a dependent variable, rate of sag/puncture stress was also statistically studied.

Results and Discussion

Chemical composition and gel characteristics

Low-ester pections obtained were 18 Samples from HCl demethylation (from A-1 to A-18) and 20 samples from combined HCl-NH_4OH demethylation (from B-1 to B-20). As shown in Table 1, the acid treated samples (treatment A) contained ester groups in the range of 29.0-44.7% and apparent molecular weight of 62,500 – 130,500, while HCl-NH_4OH demethylation treatment B resulted an additional acid amide groups (1.8-22.4%) on carbon No. 6. The range of ester content, free carboxyl groups and apparent molecular weight of HCl-NH_4OH treated samples were relatively narrower than those of acid demethylated ones.

The HCl demethylated samples showed that increase in free carboxyl groups or decrease in ester groups caused low solubility during boiling and more pregelation during gel preparation after calcium addition. The tendency was apparent for those samples with more than 60% of free carboxyl groups. The gels prepared from acid demethylated low-ester pectin were generally observed as brittle and weak. These observations agree with the report of Black and Smit[9] who also found a weak and poor gel characteristics when the gels were prepared with low-ester pectin having high level of free carboxyl groups. The samples having molecular weight less than 115×10^3 also exhibited severely brittle gels and those samples above 40% esterification resulted in weak gels with wet surfaces.

On the other hands gels made from HCl-NH_4OH demethylated samples showed a smooth and elastic texture except those samples of B-4, B-5, B-6, B-16 and B-20 which contained a low level of acid amide groups and a high level of free carboxyl groups. The sample (B-8) containing 21.9% esterification, 55.7% free carboxyl groups and 22.4% acid amide groups exceptionally exhibited brittle and poor texture. This may be due to a very low ester content in the low-ester pectin.

Rheological/gel evaluation

All of the individual samples prepared were evaluated for their firmness by the sag and gel strength by the puncture force (Table 1). The results showed a decrease in sag, which refers to an increase of gel firmness as the ester level decreased from 44.7% to 29.0%. A strong correlation between sag and percent esterification (PES) was obtained from statistical analysis significant at a level of 0.1% (Table 2,3,4). This result agrees with Black and Smit's work[9] who also reported the firmness of the gels made by acid demethylated pectin increased as the methoxyl level decreased, and that maximum gel strength was reached at around 30.0% ester content.

The puncture stress (PS) which corresponds to gel strength of gels made by HCl demethylated samples increased steadily as the ester content decreased from 44.7% to 29.0%. This showed a significant correlation at the 5% level. Table 2 shows that more carboxyl groups in the sample causes a decrease in sag and an increase in puncture stress during the puncture test. Since % free carboxyl groups was calculated by subtracting % esterification from 100 when no amide groups were involved, correlations for free carboxyl groups will have an opposite sign to those obtained for % esterification

Table 1. Chemical and physical gel characteristics of low ester pectin prepared by HCl and HCl-NH_4OH demethylation

Samples	PES[c]	PAA[d]	PCOOH[e]	PGA[f]	MW[g] X10^3	SAG[h]	PS[i]	SAG/PS	Gel Characteristics
A-1[a]	44.72	0	55.28	98.65	130.5	20.27	0.497	40.73	Extremely weak
A-2	43.04	0	56.96	97.64	126.9	15.89	0.713	22.26	Very weak
A-3	40.99	0	59.01	98.11	120.9	11.09	1.096	10.12	Smooth
A-4	40.70	0	59.30	99.20	117.1	8.71	1.337	6.51	Brittle
A-5	39.92	0	60.08	98.92	118.0	8.85	1.396	6.34	Brittle
A-6	39.92	0	60.08	96.84	116.2	9.66	1.378	7.00	Brittle
A-7	38.58	0	61.42	98.75	108.6	7.61	1.464	5.19	Brittle
A-8	38.47	0	61.53	98.99	107.3	7.88	1.519	5.18	Very brittle
A-9	36.79	0	63.21	99.01	102.4	6.50	1.741	3.73	Very brittle
A-10	36.58	0	63.42	99.83	95.1	5.31	1.625	3.26	Very brittle
A-11	36.55	0	63.45	99.05	113.2	5.77	1.967	2.93	Very brittle
A-12	33.59	0	66.41	99.99	80.9	4.04	1.689	2.39	Extremely brittle
A-13	33.38	0	66.62	99.99	84.5	3.60	2.131	1.69	Extremely brittle
A-14	29.19	0	70.81	99.97	71.5	2.46	2.186	1.12	Extremely brittle
A-15	40.55	0	59.45	98.07	82.5	15.41	0.594	25.93	Smooth but weak
A-16	32.91	0	67.09	98.96	68.5	8.53	1.039	8.21	Brittle
A-17	30.14	0	69.86	98.49	63.4	8.32	1.045	7.95	Very brittle
A-18	29.00	0	71.00	99.38	62.5	7.81	1.120	6.97	Very brittle
B-1[b]	33.24	15.44	51.32	99.65	105.2	5.41	2.177	2.48	Smooth, elastic
B-2	33.70	10.70	55.60	99.01	103.8	5.90	1.891	3.12	Smooth, elastic
B-3	32.48	9.03	58.49	99.87	95.2	4.74	2.164	2.19	Smooth, elastic
B-4	32.33	2.34	65.33	94.12	105.0	6.02	1.791	3.36	Brittle, less elastic
B-5	31.97	2.01	66.02	93.99	98.5	5.33	1.522	3.50	Brittle, less elastic
B-6	31.42	1.84	66.74	95.09	99.5	5.46	1.927	2.83	Brittle, less elastic
B-7	38.62	14.60	46.78	96.11	121.4	14.03	0.929	15.10	Smooth, elastic
B-8	21.88	22.38	55.74	99.84	96.3	2.58	2.463	1.04	Very brittle, less elastic
B-9	36.37	9.30	55.33	98.48	107.6	6.94	1.665	4.17	Smooth, elastic
B-10	36.24	8.02	55.74	98.66	106.4	6.87	1.638	4.19	Smooth, elastic
B-11	30.84	4.26	64.90	92.11	108.7	5.52	2.087	2.64	Smooth, less elastic
B-12	36.21	21.49	42.30	99.31	111.3	7.64	1.602	4.77	Smooth, very elastic
B-13	36.40	15.99	47.61	96.86	120.0	9.90	1.457	6.79	Smooth, elastic
B-14	31.45	14.30	54.25	98.65	108.9	4.46	3.160	1.41	Smooth, elastic
B-15	29.95	6.51	63.54	94.42	105.5	4.89	2.335	2.09	Smooth, elastic
B-16	31.44	2.84	65.72	93.90	108.2	5.14	2.129	2.41	Brittle, less elastic
B-17	35.84	21.22	42.94	98.43	113.4	8.05	1.657	4.86	Smooth, very elastic
B-18	36.45	15.55	48.00	96.89	118.3	12.01	1.053	11.40	Smooth, elastic
B-19	33.73	11.50	54.77	99.17	103.3	5.71	1.973	2.86	Smooth, elastic
B-20	32.51	3.07	64.42	93.58	111.6	5.73	1.973	2.90	Brittle, less elastic

[a] A = Samples were prepared by demethylation with 4.5 N HCl at 3°C.

[b] B = Samples were prepared by demethylation with 4.5 N HCl at 3°C, followed by NH_4OH at various temperature.

[c] PES = % esterification. [d] PAA = % acid amide groups. [e] PCOOH = % free carboxyl groups.

[f] PGA = % galacturonic acid. [g] MW = molecular weight. [h] SAG = Sag in mm.

[i] PS = Puncture stress in N/cm^2.

Table 2. Correlations between chemical composition of low-ester pectin and gel characteristics for HCl demethylation

	PES	PAA	PCOOH	PGA	MW	SAG	PS	SAG/PS
PES			-[a]	-	+[b]	+	-	+
PAA								
PCOOH	-			+	-	-	+	
PGA	-		+			-	+	
MW	+		-			+		
SAG	+		-	-	+		-	+
PS	-		+	+		-		-
SAG/PS	+					+	-	

[a]- = negative correlation at 5% level.

[b]+ = positive correlation at 5% level.

Table 3. Correlations between chemical composition of low-ester pectin and gel characteristics for HCl-NH_4OH demethylation

	PES	PAA	PCOOH	PGA	MW	SAG	PS	SAG/PS
PES			-[a]		+[b]	+	-	+
PAA			-	+				
PCOOH	-	-		-	-	-		
PGA		+	-					
MW	+		-			+	-	
SAG	+		-		+		-	+
PS	-				-	-		-
SAG/PS	+					+	-	

[a]- = negative correlation at 5% level.

[b]+ = positive correlation at 5% level.

Table 4. Correlations between physical properties and chemical composition of low-ester pectins prepared by HCl and HCl-NH_4OH demethylation

	PES	PAA	PCOOH	PGA	MW	SAG	PS	SAG/PS
PES			-[a]		+[b]	+	-	+
PAA			-				+	
PCOOH	-	-			-	-		
PGA								
MW	+		-			+		
SAG	+		-		+		-	+
PS	-	+				-		-
SAG/PS	+					+	-	

[a]- = negative correlation at 5% level.

[b]+ = positive correlation at 5% level.

for acid demethylated low-ester pectin. Wiles and Smit[16] reported a tendency to loose desirable gel characteristics such as resilience and resistance to breakage as the molecular weight of low-ester pectin falls below about 120×10^3. Our result (Table 2) shows that less firmer gel, or increase in sag values was obtained as the molecular weight increased.

Table 3 shows correlations between the chemical composition of low-ester pectins produced by HCl-NH_4OH demethylation and their physical gel characteristics. The effect of ester content on gel characteristics is similar to that obtained with acid demethylated pectins. Decreasing the ester level from 38.7% to 21.9% resulted in lower sag values and higher values of puncture stress. Therefore, gels became stronger and firmer with more de-esterification. With an increase in free carboxyl groups from 43.3% to 66.7% sag significantly decreased. A higher molecular weight was related not only to an increase in sag values but also to a decrease in puncture stress.

The role of amide groups on gel characteristics of lowester pectin was investigated by several workers. Kim *et al.*[11] showed that the acid-amide groups have a strong positive effect on compressive maximum stress which indicate the elastic limits of the gel. Black and Smit[9] suggested that an increase of amide groups in low-ester pectin with relatively low levels of free carboxyl group (about 46%) may cause stronger and firmer gels. In Table 3 there was no significant relationship existed between the content of acid amide groups and physical gel properties of HCl-NH_4OH demethylated samples. However when all samples of HCl and HCl-NH_4OH demethylation were pooled and statistically analyzed (Table 4), the acid amide content affected clearly on puncture stress (at 5% level). Therefore, it can be suggested from the results in Table 1 and Table 4 that more elastic and stronger gels were resulted from an increase in acid amide groups in low-ester pectin.

The effect of other chemical characteristics, such as % esterification, % free carboxyl groups and molecular weight in samples from treatment of HCl and treatment of HCl-NH_4OH (Table 4) showed similar effects on physical characteristics as those of treatment of HCl alone (Table 2) and treatment of HCl-NH_4OH alone (Table 3). The only differences shown in Table 3 are the poor relationships (more than 5% significant level) between MW and FS.

Regression procedure

A further statistical analysis using the regression procedure was performed on chemical composition and gel characteristics in an attempt to obtain equations that could be useful for prediction of gel properties by analyzing the chemical composition and the molecular weight of demethylated samples. Using the general linear model as described in material and methods, the independent variables having high sequential (PROB) F) values over 0.1 were deleted by the principle of the backward elimination procedure[15] and the regression equation determined with the remaining variables.

After testing a number of different models to each gel property of the samples prepared by HCl and HCl-NH_4OH demethylation and a combination of them, the following equations in Table 5 were obtained. These equations have goodness of fit, R^2, over 5%. The multiple correlation coefficient on each equation, R, was calculated to find overall correlation of the independent variables to a dependent variable. In order to see the significance of overall regression, an F-test was used and all of the equations were highly significant at less than 0.3% level. Each independent variable of chemical composition was tested sequentially to find that degree of contribution to the equation.

Very high multiple correlation coefficients were found in equation for SAG ($R = 0.852$), PS ($R = 0.819$) and SAG/PS ($R = 0.753$) in HCl demethylation, and SAG ($R = 0.893$) and SAG/PS ($R = 0.781$) in HCl-NH_4OH demethylation. From the total samples of HCl and HCl-NH_4OH treatment, the equation for SAG ($R = 0.765$) and PS ($R = 0.760$) were also found to be highly correlated with chemical composition. These equations show a good fit to experimental data and could be valuable tools in predicting the sag and puncture stress from the chemical composition of low-ester pectins. For instance, the changes of the sag values in HCl demethylation are strongly influenced by the changes of percent esterification, percent galacturonic acid and molecular weight. This equation also shows sag is influenced most significantly by percent esterification followed by molecular weight and percent galacturonic acid. The probability test (F-test) shows that the overall equation is statistically significant at the 0.05% level.

Table 5. Linear regression equations which have R^2 over 50%

HCl demethylation

SAG = 132.525 + 1.226(PES) - 1.554(PGA) - 0.157(MW)

Overall model ; multiple correlation coefficient = 0.8517
Overall model ; PROB > F = 0.0005
PES ; PROB > F = 0.0001
PGA ; PROB > F = 0.0556
MW ; PROB > F = 0.0309

PS = -17.885 - 0.142(PES) + 0.222(PGA) + 0.026(MW)

Overall model ; multiple correlation coefficient = 0.8188
Overall model ; PROB > F = 0.0014
PES ; PROB > F = 0.0062
PGA ; PROB > F = 0.0210
MW ; PROB > F = 0.0046

SAG/PS = -68.2178 + 3.307(PES) - 0.454(MW)

Overall model ; multiple correlation coefficient = 0.7526
Overall model ; PROB > F = 0.0026
PES ; PROB > F = 0.0026
MW ; PROB > F = 0.0211

HCl-NH_4OH demethylation

SAG = -21.958 + 0.2964(PES) - 0.0305(PCOOH) + 0.1907(MW)

Overall model ; multiple correlation coefficient = 0.8930
Overall model ; PROB > F = 0.0001
PES ; PROB > F = 0.0001
PCOOH ; PROB > F = 0.0903
MW ; PROB > F = 0.0055

SAG/PS = -32.8105 + 0.2922(PES) + 0.2546(MW)

Overall model ; multiple correlation coefficient = 0.7811
Overall model ; PROB > F = 0.0005
PES ; PROB > F = 0.0004
MW ; PROB > F = 0.0170

HCl and HCl-NH_4OH demethylation

SAG = -14.840 = 0.6436(PES)

Overall model ; multiple correlation coefficient = 0.7654
Overall model ; PROB > F = 0.0001
PES ; PROB > F = 0.0001

PS = 4.062 - 0.1133(PES) + 0.0148(MW)

Overall model ; multiple correlation coefficient = 0.7597
Overall model ; PROB > F = 0.0001
PES ; PROB > F = 0.0001
MW ; PROB > F = 0.0019

References

1. Owens, H.S., McCready, R.M. and MaClay, W.D.: *Food Technol.*, **3**, 77 (1949)
2. Joseph, G.H.: In *advances in Chemistry Series*, No. 12, American Chemical Society, Washington, D.C., p. 49 (1955)
3. Kim, W.J., Sosulski, F. and Campbell, S.J.: *J. Food Sci.*, **43**, 746 (1978)
4. Kim. W.J., Sosulski, F. and Lee, S.C.K.: *J. Food Sci.*, **43**, 1436 (1978)
5. Joseph, G.H., Kieser, A.H. and Bryant, E.F.: *Food Technol.*, **3**, 85 (1949)
6. Speiser, R. and Eddy, C.R.: *J. Am. Chem. Soc.*, **68**, 287 (1946)
7. Doesburg, J.J.: *Communication No. 25*, Inst. for Research on Storage and Processing of Horticultural Produce, I.B.V.T. Wagenigen, The Netherlands (1965)
8. Black, S.A. and Smit, C.J.B.: *J. Food Sci.*, **37**, 726 (1972)
9. Black, S.A. and Smit, C.J.B.: *J. Food Sci.*, **37**, 730 (1972)
10. Baker, G.L. and Goodwin, M.W.: *Delaware Agr. Exp. Sta. Bul.* No. 234, p. 48 (1941)
11. Kim, W.J., Rao, V.N.M. and Smit, C.J.B.: *J. Food Sci.*, **43**, 572 (1978)
12. Kim, W.J., Smit, C.J.B. and Rao. V.N.M.: *J. Food Sci.*, **43**, 74 (1978)
13. A.O.A.C.: *Official Methods of Analysis*, 11th ed., Association of Official Analytical Chemists, Washington, D.C., p. 391 (1970)
14. National formulary.: American Pharmaceutical Association, 12th ed., Washington, D.C., p. 291 (1965)
15. Draper, N.R. and Smith, H.: In *Applied Regression Analysis*, John Wiley and Sons, Inc., New York, N.Y.P. 163 (1966)
16. Wiles, R.R. and Smit, C.J.B.; *U.S. Patent* No. 3, 622, 599 (1971)

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Low-ester Pectin Gel의 단단함과 强度의 예측

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High-ester pectin을 HCl 단독 또는 HCl과 NH_4OH를 병용하여 demethylation 시킨뒤 얻어진 low-ester pectin(LM pectin)으로 gel을 제조하였다. LM pectin gel의 단단함과 强度를 측정한 결과 HCl로 처리된 LM pectin gel은 일반적으로 强度가 약하고 거칠며 탄력이 없었다. 반면 HCl-NH_4OH로 처리한 LM pectin gel은 텍스쳐가 부드럽고 탄력이 좋았다. 물리적 성질에 대한 LM pectin의 화학적 조성의 상관 관계에서 단단함(Sag값)에 대한 ester함량 및 분자량, 그리고 强度(puncture stress)에 대한 amide 및 ester함량 또는 분자량 간에는 유의성 있는 관계가 밝혀졌다. 상관성이 높은 화학적 인자에서 LM pectin gel의 물리적 성질을 예측할 수 있는 관계식을 산출하였다.