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Expression Characteristics of Chinese Cabbage

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ABSTARCT

Expression of chinese cabbage was conducted in order to investigate its dewaterring behavior. Chopped cabbage was packed into cylinder and pressed by piston upto the predetermined pressure on Instron-1000. The rates of dewatering were affected domintantly by the applied pressure, but not significantly by the packed amount of cabbage in the cylinder. The pressure effect was increased very abruptly at first, but the increase rate was very low at high pressure greater than 20 MPa, showing great deviation from linear dependence of flow rate on pressure in Darcy's Law. Therefore, water expression from cabbage was not Newtonian flow of water through cell wall. In fact, the squeezed water contained a lot of solid particles, showing destruction of cell wall. The content of solid particles in expressed water was only slightly lower than the dry matter content of fresh chinese cabbage, determined by drying oven method.

Key Word : Expression, Dewatering, Cabbage, Pressure

INTRODUCTION

Chinese cabbage is widely produced in Korea and mostly consumed as the raw material for Kimchi, the most important side dish for Korean meals. Since the cabbage is transporting to the whole sale market of metropolitan areas without any processings at the producing areas excepting wrapping it with old papers, and cabagge trimming is usually conducting in the whole sale market. According to news from Karak agricultural and fishery whole sale market, about 300 tons of daily garbage from chinese cabbage and radish were resulted from trimming process. The management department of the market paid 200 million won last year for garbage transportation to waste dumping area. Furthermore, dumped vegetable waste are not only to cause environmental pollution, but also to waste renewable resources, because it may be used as inorganic fertilizer or feed for livestocks after appropriate treatments.

Like most other vegetables, moisture content of chinese cabbage is very high, more than 90 percents. The dumped vegetable garbage with high moisture content is hard to be decayed, since lactic acid fermentation is initiated in the anaerobic condition within the dumped material, a common situation in the storage of high moisture foods, and then the produced acids lower down pH preventing the material from decaying. Obviously, the anaerobic condition is not beneficial in order to increase the decaying rate of vegetable garbage, although it is good for preservation of food. Thus, in order to reduce pollution problem, it is beneficial to lower moisture content or to remove water from vegetable garbage by mechanical or other ways. The adequate method must extract the most portion of liquid from vegetables, so that the separated solid part can become sufficiently aerobic. The dewatered vegetable may be treated later differently for its own purpose.

Expeller can be used for expression of water from vegetable with some modifications, although its original usage is oil extraction. The principle of extraction is simple; as the screw is rotating, the material goes forward, by which pressure is built up in the other end, and then the built up pressure expell the liquid to radial direction from the material. But we need some basic information on the relationship of pressure and dewatering of chinese cabbage in order to modify or design the expeller.

No studies were carried out to investigate the relationship between dewatering and pressure for vegetables. Therefore, in order to find design factors in designing expeller, this study is focused on the dewatering characteristics and compression effects of chinese cabbage.

MATERIALS AND METHODS

Liquid portion was expressed from chinese cabbage packed in cylinder-piston mechanism pressed on Instron-1000. Two different sets of cylinder-piston were constructed for and fixed to the Instron test machine. Fig. 1 shows the overall experimental set up and Fig. 2 shows the schmatic diagram of cylinder-piston packed with chopped cabbage. The specifications of the experimental set up were tabulated in Table 1.

Experimental Design

In order to figure out the compression characteristics of cabbage three different pressure levels and three different packing levels of cabbage were tested with three replications. Table 2 shows the experimental variables.

Sample Preparation and Test Method

The material used in this study was chinese cabbage. The cabbage, two or three days passed after harvest, was chopped to about 0.5 cm X 0.5 cm. No chemical treatments were applied to the cabbage. The moisture content of the cabbage used in this study was 94% determined by drying oven method. Predetermined amount of chopped cabbage was weighed, packed into the cylinder-piston, and expressed by the force of Instron 1000.

At fixed cross head speed of 10mm/minutes, we let the head move down until the pressure reached to the predetermined pressure value as shown in Table 2.

Then, the travel distances of cross head were kept at each measurement for later analysis. After that, the pressed cabbage was removed from the cylinder-piston and we measured its thickness and weight. The same procedure was repeated during the whole test runs. The expressed water from the pressed cabbage in the cylinder was freely run down along the inner surface of the cylinder or through the holes on the top of the piston. Along with the data collection, we could obtain the pressure built up diagram inside the cylinder packed with chopped cabbage from the printer attached to the Instron.

RESULTS AND DISCUSSIONS

Compression Characteristics of Chinese Cabbage

The expression data at different pressures and different amounts of cabbage were shown in Table 3. The pressure were calculated by the section area of piston and applied forces. Initial volume was also calculated on the basis of the cross section area of piston and the thickness of packed cabbage at zero basis, while final volume from the thickness of pressed cabbage. The amount of dewater, Dew, was calculated to be the difference between the initial and final weight of cabbage. Dewatering rate was defined to be Dew/I.W. and determined on the basis of Dew and initial weight. Dewatering rate dependence on pressure, Dew/MPa, was calculated from Dew and pressure. We observed that the required pressure built up was accomplished so quickly inside the cylinder, less than one minute.

Pressure Effects on the Dewatering Rate, Dew/I.W.

In relation to designing expeller for dewatering of cabbage, the relationship between pressure and dewatering is important for planning dewatering schedule along expeller screw. The rate of dewatering, Dew/I.W., was affected dominantly by the applied pressure as shown in Fig. 3, but not so significant by the packed amount of cabbage in Fig. 4. The pressure effect was increased very abruptly at first, but the increase rate was very low at high pressure greater than 20 MPa, showing great deviation from linear dependence of flow rate on pressure in Darcy's Law. Therefore, water expression from cabbage was not Newtonian flow of water through cell wall.In fact, the squeezed water contained a lot of solid particles, showing destruction of cell wall. The content of solid particles in expressed water was only slightly lower than the dry matter content of fresh chinese cabbage, determined by drying oven method. A view point from efficient dewater production and pollution control in terms of clear dewater production from vegetables, ultra filteration membrane with finely grounded vegetable could be an alternative vegetable treatment method.

Dewatering Rates at Different Pressure as Affected by Packed Cabbage Amounts

Fig. 5 and Fig. 6 shows the effect of packed amount on the dewatering rates at different levels of pressure. The figure indicated that the greater the amounts, the more dewaters were produced. In other words, the dewater quantities were proportional to the initial amounts of packed cabbage at certain pressure.

Dewatering Rates at Different Packed Amounts of Cabbage in the Cylinder

Fig. 7 shows the effect of packed amount of cabbage in the cylinder. The dewatering rate was defined as the ratio of the total dewater vs the pressure and the packed amount of cabbage in the cylinder. There was no consistent tendency between the dewatering rate and the initial cabbage weight in the cylinder. Similar results were shown in Fig.2.

Cabbage Volume Compression by Cabbage Expression

Fig. 8 shows the change of loads and cabbage volumes of packed cabbage in the cylinder, initial cabbage amount, 41.4 g, cross section area, 6.357cm2, where the cross head was moving down at constant speed of 10 mm/min. Load was almost linearly increased to 4500 Newtons when the cross head was moving down, and the volume of packed cabbage was increased to 40% of the original volume.

CONCLUSIONS

Dewatering characteristics of chopped cabbage was studied using Instron test machine where two different load area of cylinder-piston were used and pressure range was from 7.7MPa to 27.7 MPa. We assumed that two factors, pressure and packed amount, were very important to determine dewater of cabbage. Within the pressure range, it turned out that the pressure effect on the dewatering was clear that the higher pressure the more dewater was produced. While the effect of packed cabbage amount was not so significant as that of pressure. The pressure effect was increased very abruptly at first, but the increase rate was very low at high pressure greater than 20 MPa, showing great deviation from linear dependence of flow rate on pressure in Darcy's Law. Therefore, water expression from cabbage was not Newtonian flow of water through cell wall.In fact, the squeezed water contained a lot of solid particles, showing destruction of cell wall. The content of solid particles in expressed water was only slightly lower than the dry matter content of fresh chinese cabbage, determined by drying oven method.

REFERENCES

1. Esaki, H., T. Satake, K. Guo and M. Yashiro. 1985. Research on the pelletization of biomass (Part 1). J. Japanese Society of Agricultural Machinery. 47(3):279-284

2. Esaki, H., T. Satake and K. Guo. 1986. Research on the pelletization of biomass (Part 2). J. Japanese Society of Agricultural Machinery. 48(1):83-90

3. Faborode, M.O. and J.R. O'Callaghan. 1986. Theoretical analysis of the compression of fibrous agricultural materials. J. agric Engng Res. 35:175-191

4. Kim, Y.J., C.R. Engler, C.G. Coble and R.P. Egg. 1988. Clostridial fermentation of high energy sorghum. ASAE Paper No. 88-6005, St. Joseph, MI.

5. O'Dogherty, M.J. and J.A. Wheeler. 1984. Compression of straw to high densities in closed cylindrical dies. J. agric. Engng Res. 29:61-72

Table 1. Specification of the experimental appartus

Item	Specification	Remark
Instron-1000	force range: 0 - 4.9KN crosshead speed: 10-500mm/min.	Plotter attached
Piston-cylinder-1		
cylinder	diameter: 1.5cm length: 23.3cm	
piston	section area: 1.767cm^2 maximum pressure: 27.73 MPa	
Piston-cylinder-2		
cylinder	diameter: 2.845cm length: 27.8cm	
piston	section area: 6.357cm^2 maximum pressure: 7.7MPa	

Table 2. Experimental variables and their levels

Variables	Levels	No. of levels
For piston-cylinder-1(section area=1.767cm^2)		
Pressure	27.73, 16.64, 8.31 MPa	3
Packed amount	2.16, 4.31, 6.46 Grams	3
For piston-cylinder-2(section area=6.357cm^2)		
Pressure	7.7 MPa	1
Packed amount	13.69, 27.43, 41.11Grams	3

Table 3. Compression data at different force levels and different sample amount (average of three replications)

Initial wt. (g)	Final wt. (g)	Travel dist. (mm)	Initial vol. (cm^3)	Final vol. (cm^3)	Initial den. (g/cm^3)	Final den. (g/cm^3)	Dew (g)	Dew/ MPa (g/MPa)	Dew/ I.W. (g/g)
Cylinder area = $1.767cm^2$									
P= 27.73MPa									
2.16	1.25	7.8	2.44	1.06	0.88	1.19	0.9	0.033	0.418
4.32	2.34	14.47	4.41	1.85	1.01	1.29	1.97	0.071	0.457
6.46	3.09	24.3	6.7	2.4	0.97	1.28	3.38	0.121	0.522
P= 16.64MPa									
2.16	1.06	6.17	1.91	0.82	1.15	1.34	1.09	0.065	0.506
4.31	2.63	15.07	4.76	2.09	0.93	1.26	1.69	0.101	0.390
6.64	3.56	20.4	6.41	2.81	1.04	1.27	3.08	0.185	0.463
P= 8.31MPa									
2.16	1.53	7.03	2.37	1.13	0.92	1.36	0.62	0.075	0.289
4.31	2.77	13.37	4.54	2.18	0.95	1.28	1.55	0.186	0.358
6.46	4.41	14.07	6.29	3.8	1.03	1.16	2.06	0.247	0.318
Cylinder area = $6.457cm^2$									
P= 7.7MPa									
13.69	9.9	13.67	18.55	9.86	0.74	1	3.8	0.493	0.277
27.43	20.3	25.53	36.61	20.37	0.75	1	7.13	0.926	0.259
41.11	29.48	27.77	46.81	29.16	0.89	1.01	11.63	1.510	0.283

1.* are measured values, others are calculated.

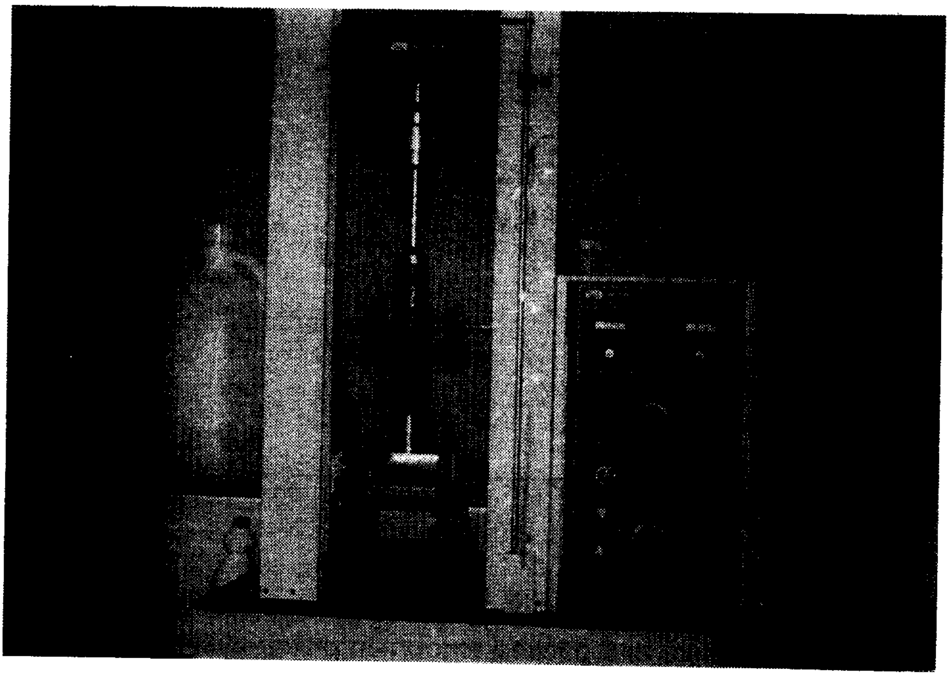

Fig. 1. Photograph of the dewatering test set up

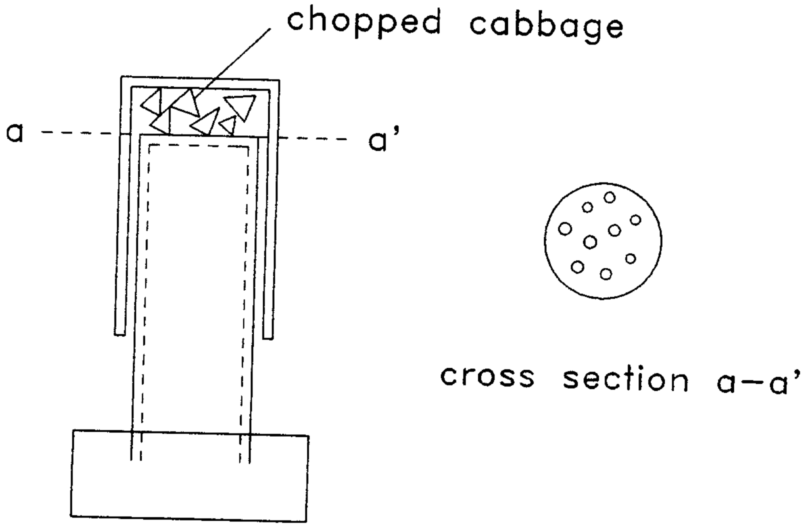

Fig. 2. Schematic diagram showing piston-cylinder

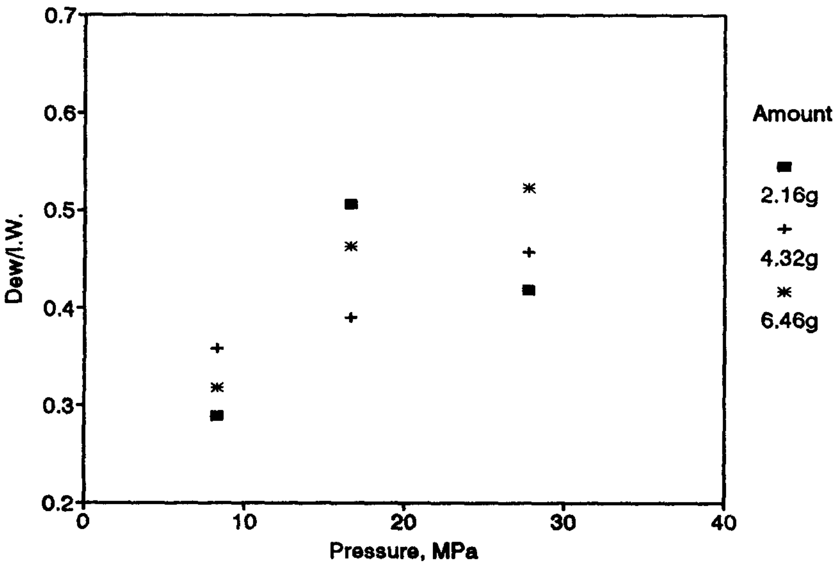

Fig. 3. Dewatering rates of chinese cabbage affected by applied pressure and packed amount in piston-cylinder-1

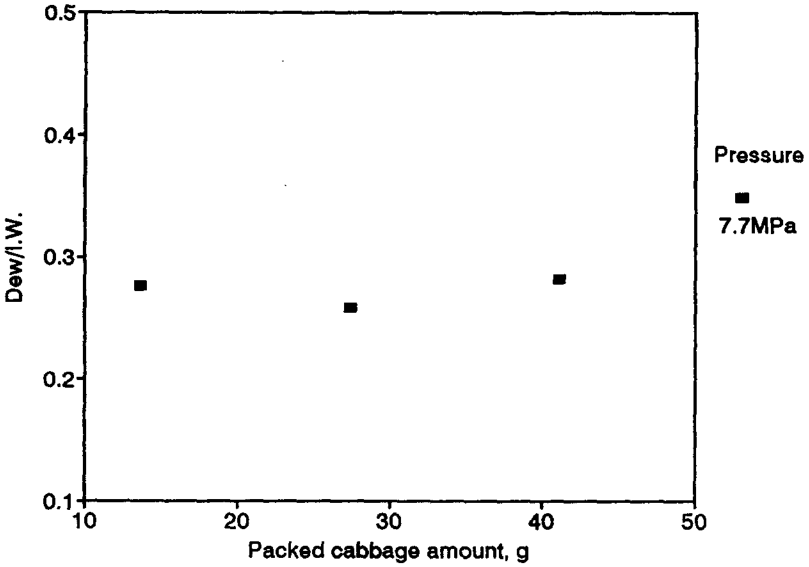

Fig. 4. Dewatering rates at different packed amount of chinese cabbage in piston-cylinder-2

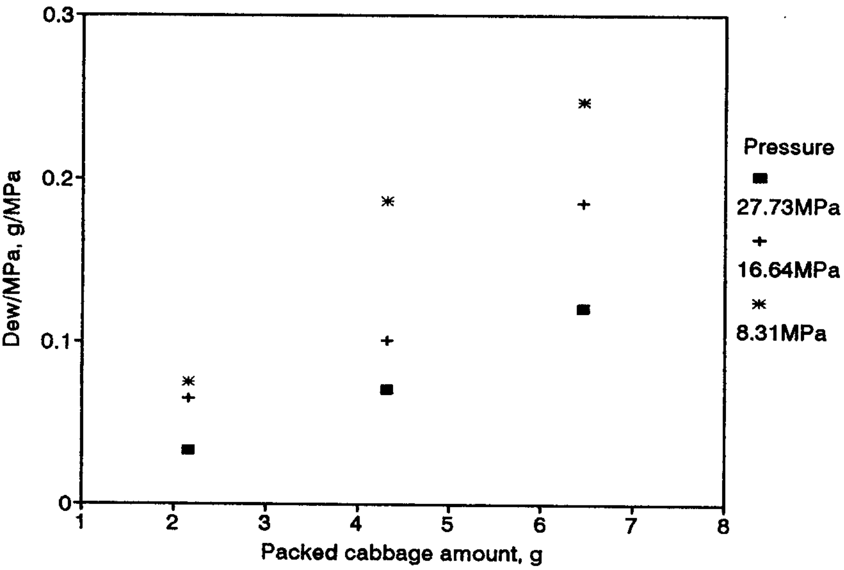

Fig. 5. Dewatering rates at different packed cabbage amounts in piston-cylinder-1

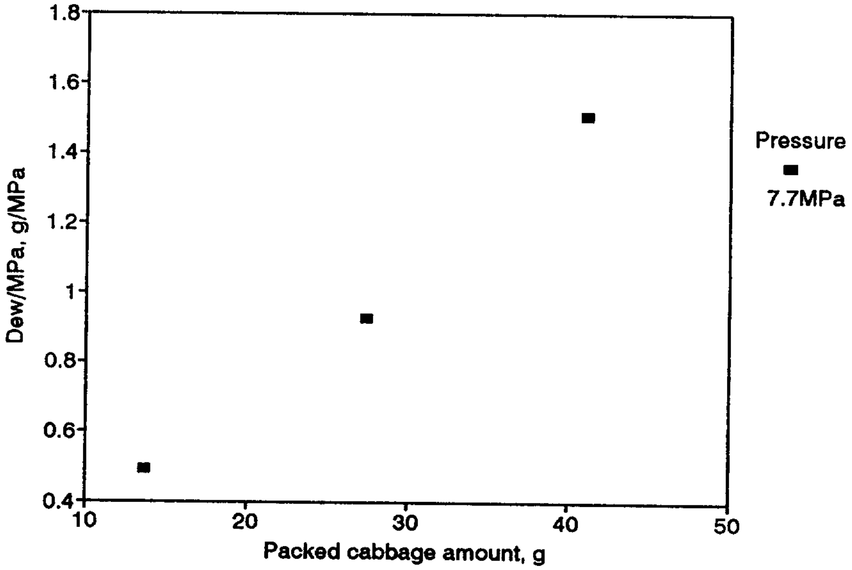

Fig. 6. Dewatering rates at different packed amount of chinese cabbage in piston-cylinder-2

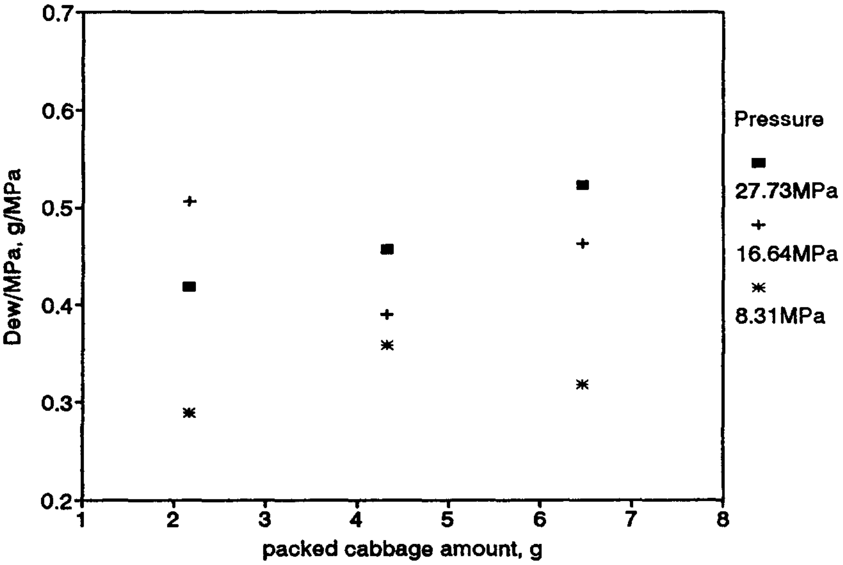

Fig. 7. Dewatering rates at different packed amounts of chinese cabbage in piston-cylinder-1

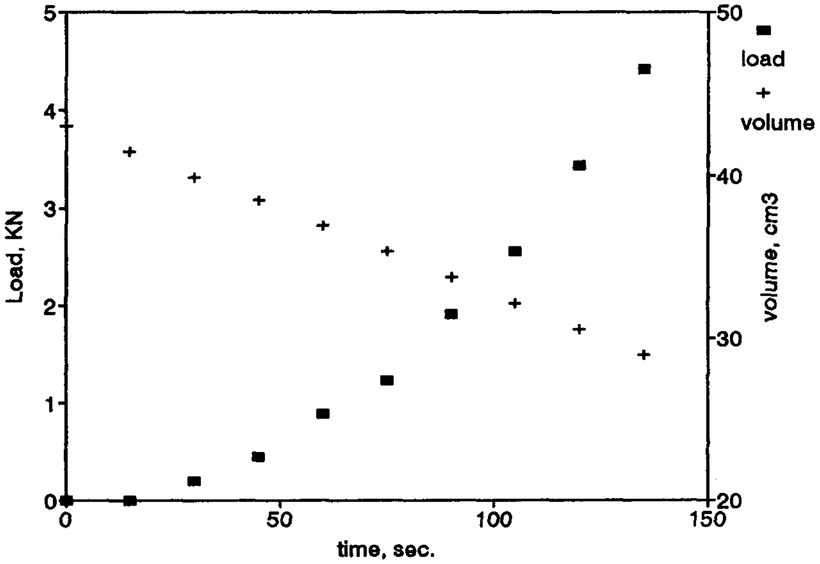

Fig. 8. Compression curve for cabbage, packed amount, 41.1g, cylinder-piston-2