STUDIES ON THE SWELLING OF FOODS III. ON THE DETERMINATION OF THE SWELLING VELOCITIES BY THE WEIGHING METHOD

By

Kazushige SATO and Sin NAGASAWA

Department of Food Chemistry, Faculty of Agriculture, Tohoku University, Sendai, Japan

(*Received, October 24, 1961*)

When dehydrated foods absorb water and swell, the total volumes of the water and of the samples must decrease, but in the case of rices the total volume increase at the first stage of swelling (1). As these phenomena are very abnormal from the common point of view, the authors attempted to determine the swellng velocities of several kinds of cereals by the same method (2). But with any sample, the abnormal phenomenon of this sort did not appear so clearly as with rices, and even with rice, this phenomenon disappeared when its grain was cracked.

This abnormal phenomenon was discovered in the method by which the fluctuations of the total volumes are measured. Thus, the authors compared those values with those of the swelling velocities obtained by weighing of the samples.

Experimental

Details of the experimental procedure which is called "the weighing method" by the authors are given as follows.

The sample is soaked in water at a fixed temperature; after it is left to settle for the required time at the same temperature, the sample is removed from the water, and the swelling up to that time is determined by weighing.

This is the most direct method to determine the swelling velocity. But, the weakest point of this method is in that water which adheres to the sample cannot be perfectly wiped away; therefore, there is some doubt whether the increased weight of the sample comes only from the absorbed water or if the adhered water may have some relation with it.

The most common method to wipe adhered water is by the use of absorbent gauze, absorbent cotton or filter paper. When the sample is taken out of water, the surface is wiped by using them. But during wiping, if too much care is

taken in wiping, not only the adhered but the adsorbed water nay be sucked up by the wiper, while on the contrary, if the sample is wiped too briefly, a part of the adhered water may be measured together. So, the errors of values which are measured by this method are rather large either way. But, if the constance of the method is kept by which the sample and water are separated, certain comparative values can be determined. Accordingly, the authors conceived the following method, and measured the velocities of swelling of several kinds of cereals.

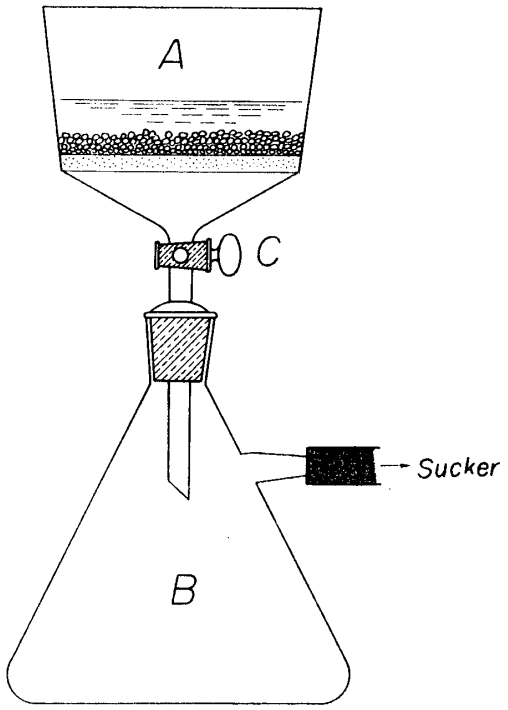

Fig. 1. The design of the measuring apparatus.

The design of the measuring apparatus is shown in Fig. 1. In this figure, (A) is a kind of glass filter in which G4-filter glass is used, and the parts marked (B) is the usual filtering bottle.

A suitable quantity of the sample is kept at the measuring temperature (in this experiment 20°±0.2°C is adopted) for one whole day and night with due care not to sorp moisture, and then the water which was kept at the same temperature is added to the sample. After the sample which is soaked in water is left to settle in the thermostat for the appointed hour, the sample and water are emptied into the filter (A).

When the air in the bottle (B) is exhausted with a sucker the stopcock (C) is opened and the water on the filter plate is swiftly run off into the bottle: and then, when no water drips from the filtering plate for 10 sec, the cock (C) is closed and the sample is transfused into a weighing tube to be weighed with a balance.

The samples—barley, rices and rape seed which were used in these experiments are of the same kind as used in the previous reports.

Results

The results of measurements are shown in Tables 1—4 and Fig. 2. Every measurement was done more than thrice and the values were rather uniform. Figures 3—6 are the graphs whose abscissa expresses the values which were measured by the method of total volume, and the ordinate the values measured

by the weighing method.

Table 1. The swelling velocity of **barley** by the weighing method.

Time	Weight of water being absorbed by 50g of sample			
	1st experiment	2nd experiment	3rd experiment	Mean
0min				0.00g
10	10.90g	10.87g	10.80g	10.86
20	13.46	13.55	13.61	13.54
30	15.22	15.20	15.20	15.21
40	15 99	16.62	16.60	16.40
50	18.20	18.05	18.16	18.12
1hr	19.12	18.88	19.24	19.08
2	24.94	24.73	24.84	24.84
3	28.49	28.85	28.24	28.53
4	31.34	31.13	31.02	31.16
5	33.13	33.24	32.97	33.11
6	34.34	34.30	34.39	34.34
7	35.30	35.30	35.05	35.22
8	35.97	36.18	36.09	36.08
9	36.64	36.32	36.58	36.51
10	36.96	36.68	37.10	36.91
11	37.79	37.78	37.31	37.63
12	38.22	38.03	38.03	38.09
13	38.19	38.54	38.44	38.39
14	38.46	38.81	38.70	38.66
15	38.74	38.95	38.83	38.87

Table 2. The swelling velocity of **rice** (**Sasasigure**) by the weighing method.

Time	Weight of water being absorbed by 50g of sample (mean value)	Time	Weight of water being absorbed by 50g of sample (mean value)
0min	0.00g	1hr	11.23g
10	6.60	2	12.03
20	7.72	3	11.81
30	8.93	4	12.82
40	9.54	5	12.64
50	10.40	6	12.60

Table 3. The swelling velocity of **rice** (**Miyakogane-moti**) by the weighing method.

Time	Weight of water being absorbed by 50g of sample (mean value)	Time	Weight of water being absorbed by 50g of sample (mean value)
0min	0.00g	5hr	12.69g
10	4.36	6	13.41
20	5.01	7	15.08
30	5.44	8	14.75
40	5.74	9	15.31
50	5.89	10	15.66
1hr	6.79	11	15.79
2	9.08	12	16.12
3	10.24	13	15.95
4	12.02		

Table 4. The swelling velocity of **rape seed** by the weighing method.

Time	Weight of water being absorbed by 50g of sample (mean value)	Time	Weight of water being absorbed by 50g of sample (mean value)
0min	0.00g	2hr	17.85g
10	6.10	3	22.35
20	8.40	4	28.30
30	8.36	5	27.79
40	9.76	6	27.68
50	11.41	7	28.27
1hr	17.62		

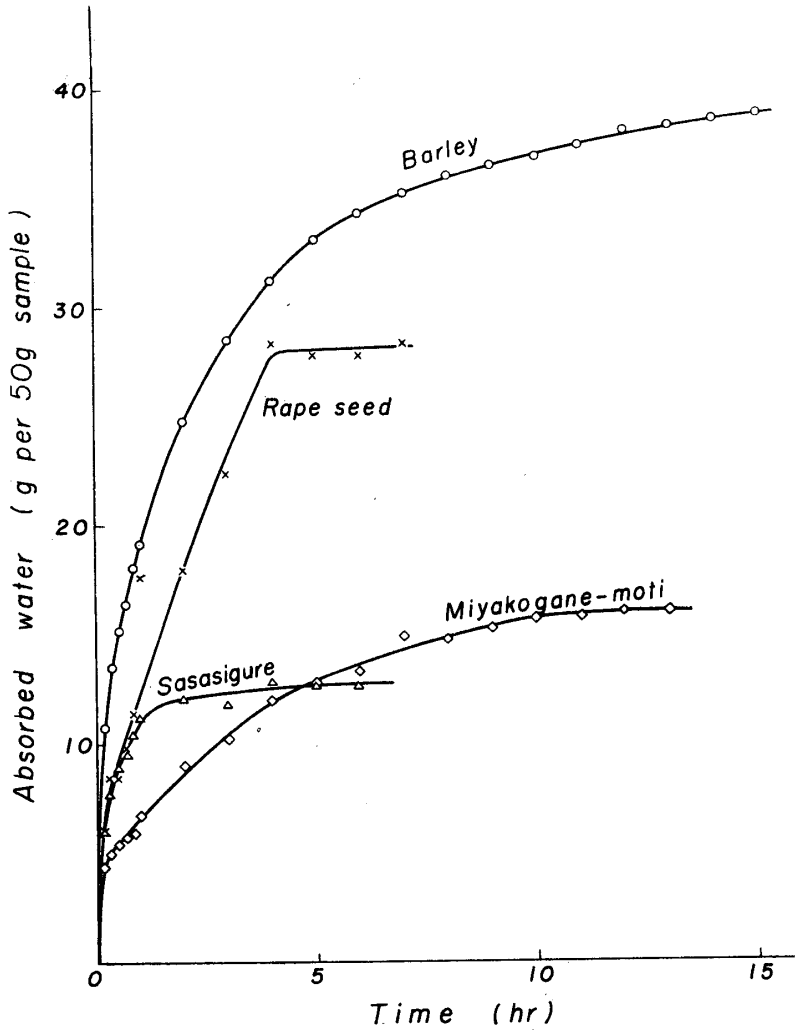

Fig. 2. The swelling velocities of barley, two kinds of rice and rape seed by the weighing method.

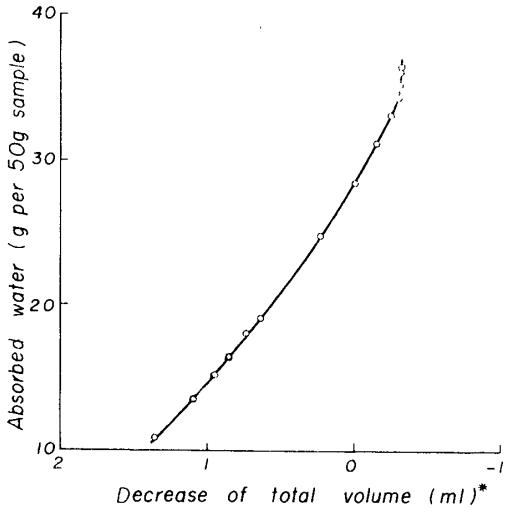

Fig. 3. The relation between the values which were measured by the total volume method and the values measured by the weighing method in the case of **barley.**
(*: cf. the previous report)

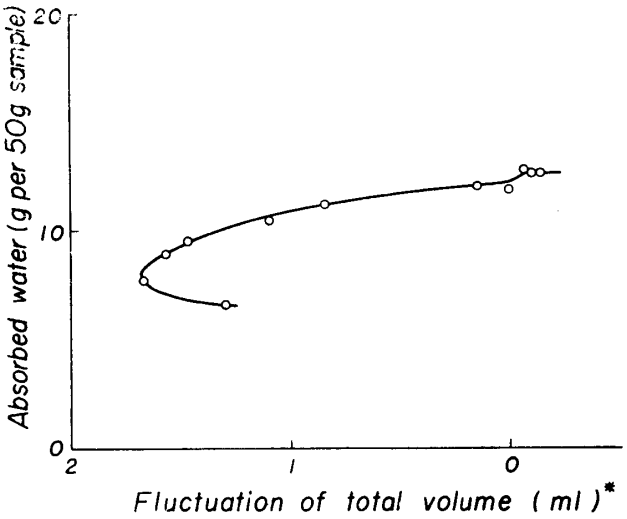

Fig. 4. The relation between the values which were measured by the total volume method and the values measured by the weighing method in the case of **Sasasigure.**
(*: cf. the previous report)

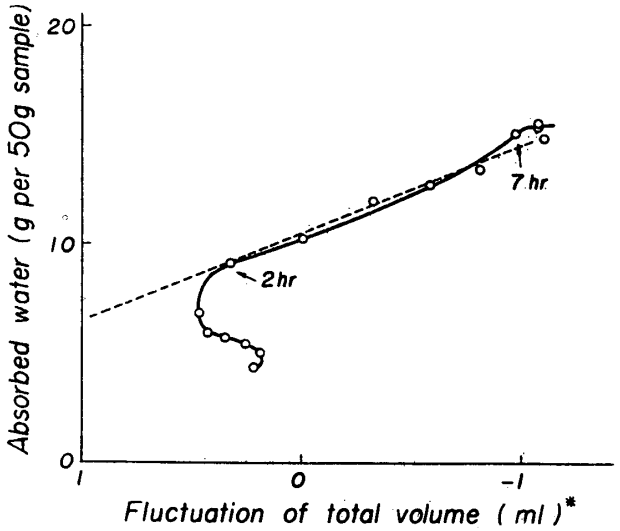

Fig. 5. The relation between the values which were measured by the total volume method and the values measured by the weighing method in the case of **Miyakogane-moti.**
(*: cf. the previous report)

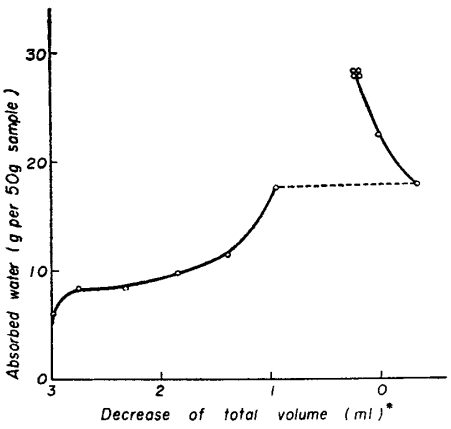

Fig. 6. The relation between the values which were measured by the total volume method and the values measured by the weighing method in the case of **rape seed.**
(*: cf. the previous report)

Discussion

Remarkable abnormal phenomenon disappeared in the four samples which were measured with the weighing method. They give comparatively smooth curves, and their shapes are the same as those which are ordinarily known as

the velocity curves of swelling.

As the authors explained in the first paper of this project, the relation curve between the total volume decreases and the quantity of absorbed water must be a rectilinear or a simple curved line, and this relation in the authors' case corresponds to the curves in Figs. 3—6. In these figures, the curve of barley is typical, and the empirical formulas of this relation are as follows:-

From 10 min to 40 min,

$$W=9.268 \log t+1.54$$

From 50 min to 4 hr,

$$W=19.44 \log t-15.28$$

From 5 hr to 15 hr,

$$W=12.03 \log t+3.58$$

(In those formulas W are the weights of water being absorbed by 50 g of the samples, and t the times for which the samples are soaked in water.)

The curves of two kinds of rice, Sasasigure and Miyakogane-moti, however, show labyrinthine shapes, and therefore it must be thought that these indicate some abnormal phenomena. But of them, especially in the case of Miyakogane-moti, the values from 2 hr to 7 hr can be formularized by the some empirical formula, as follows:-

$$W=10.48-4.11V$$

(In this formula, W is the weight of water being absorbed by the 50 g of sample, and V is the total volume decrease (*ml*) in the case which 150 g of the sample is used.)

The values of the decrease of total volume corresponds with the values of absorbed water measured by the weighing method can be calculated by this formula, and those values are plotted in Fig. 5 with a broken line. The shape of the curve resembles closely that of barley on the whole. It is still open to question what the values calculated in this way mean, but if, as the authors supposed in the previous reports, the abnormal phenomenon takes place only at the first stage of the swelling, and will revert to the normal state as time goes by, the differences between the values calculated by the above-mentioned method and values observed by the total volume method indicate the magnitude of abnormality.

Summary

The swelling velocities of barley, two kinds of rice and rape seed were measured by the weighing method. The velocity curves show normal shape, and no abnormal phenomenon was observed. But the relation between those

values and the values measured by the total volume method is normal only in the case of barley, and abnormal with the other samples. So, the authors find that the abnormal phenomena which appeared on the values of total volumes do not appear on the values of the increase of absorbed water which are measured by this weighing method.

References

1) Sato, K., S. Nagasawa (1960). Tohoku J. Agr. Res., **11**, 307.
2) Sato, K., S. Nagasawa (1961). Tohoku J. Agr. Res., **12**, 63.