Use of a Penetrometer for Measuring Rheological Characteristics of Biscuit Dough

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ABSTRACT

The penetrometer generally used for measuring the consistency of fat was modified to determine various rheological characteristics of biscuit dough. A metallic disk with a provision to increase the compression weight was introduced in place of a penetrometer cone. The dough was compressed for 10 sec and allowed to recover for 60 sec by removing the weight. It was found that 410 g was the optimum compression weight for biscuit dough (2.2 cm diameter × 1 cm height). The studies indicated that a significant correlation existed between compliance values ($r = 0.87$, $P < 0.01$) and elastic recovery values ($r = 0.74$, $P < 0.01$) as measured by penetrometer and viscoelastograph. The compliance and elastic recovery values depended on mixing time and on the amount of water added. The elastic recovery, which indicated the development of dough, was high in dough either mixed for a longer period (4 min) with a smaller amount of water (26%) or mixed for a shorter period (2 min) with a greater amount of water (30%). The elastic recovery of biscuit dough made from medium-hard flour was always higher at any condition when compared with the dough made from soft wheat flour.

Dough is the intermediate product in the transformation of flour to end product. The rheological characteristics of the dough are important, as they influence the machinability as well as the quality of the finished product (Faridi and Faubion 1986). These characteristics depend on type of flour, quantity and quality of ingredients used, and mixing and resting conditions (Bloksma and Bushuk 1988).

Although considerable information is available on rheology of bread dough (Hoseney et al 1979, Frazier et al 1985), the literature on short-biscuit dough is scanty (Steele 1977), particularly with respect to methods of assessment and factors affecting assessment. However, some work has been reported on the characteristics of cookie doughs, which are quite different from biscuit doughs in that the consistency of the dough is much softer.

Miller (1985) reported that the Stevens LFRA texture analyzer could be used to measure the consistency of biscuit dough, which correlated to the subjective assessment score. In this method, the force required for a cylinder to penetrate through dough to a predetermined depth is measured. The method has limitations, because the results depend largely on the packing of the dough into the cup. Development of a simple and less expensive method is needed. Here, a penetrometer normally used for measuring the consistency of fats was modified for measuring the rheological characteristics of biscuit dough. The results are presented in this article.

MATERIALS AND METHODS

Flour

Flour obtained by milling commercially grown soft wheat variety HD 2285 (National Seed Corp., Pusa complex, New Delhi) (flour A) and two other commercial flour samples from a local market (flours B and C) were used in the studies.

Flour Analysis

Moisture, ash, gluten, farinograph, and extensigraph characteristics were determined using AACC methods 44-15A, 08-01, 38-10, 54-21, and 54-10, respectively (AACC 1983). Alkaline water retention capacity (AWRC) was determined according to the method of Yamazaki (1953).

Biscuit Formula and Ingredients

Biscuit dough was prepared according to the formula shown in Table I. Commercially available bakery shortening (Marvo brand) and powdered sucrose were used in the preparation.

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Dough Mixing and Handling

All doughs were mixed in a Hobart N-50 mixer at 58 rpm with a flat beater. All ingredients were incorporated at once and mixed for 2, 3, and 4 min with three varying water levels (26, 28, and 30%). The doughs were sheeted to uniform thicknesses of 0.8 and 1 cm using a rolling pin and rectangular frame and then cut into cylindrical disks 2.2 cm in diameter. These disks were rested for 1 hr in a covered petri dish to assess the compliance and elastic recovery using the viscoelastograph and penetrometer.

Measurement of Dough Characteristics

Generally the penetrometer is used to determine the consistency of fats on the basis of the distance moved by the cone or needle through the material in a particular time. The circular dial gauge attached to the equipment is used to measure the distance traveled by the penetrating needle or cone through the material. The automatic timer arrests the movement of the needle after the specified period.

The penetrometer (Fig. 1) was modified for measuring the biscuit dough compliance and elastic recovery by introducing a circular metallic plate 4.5 cm in diameter and 0.15 cm thick instead of a cone. A dough disk 2.2 cm in diameter and 1 cm in height prepared as described earlier was placed on a flat plate (20 × 15 cm) kept below the compression plate. The compression plate was covered with a polyethylene sheet, and the surface of the flat metallic plate used for placing the sample was coated with paraffin oil to reduce friction. The compressing weight could be increased by adding weights on the compression plate. The height of the cylindrical dough (h_1) was noted. The compression plate was carefully rested on the dough and allowed to compress on the dough for 10 sec. Immediately the height of the cylindrical dough piece (h_2) was recorded. The compression plate was lifted up, and the dough was allowed to recover for 1 min. The height of the recovered dough (h_3) was noted. From these values, percent compliance and elastic recovery were calculated from the following equations:

$$\text{Percent compliance} = \frac{h_1 - h_2}{h_1} \times 100$$

$$\text{Elastic recovery} = (h_3 - h_2) \times 10$$

These values can only be considered as rough indicators of the true rheological properties of the doughs. Preliminary studies performed using different weights, percent compliance, and elastic recovery were determined to arrive at the optimum compression weight. The weight required to obtain maximum elastic recovery was considered as the optimum.

Compliance and elastic recovery values were also determined using a viscoelastograph per the published procedure (Laignelet and Feillet 1979) under the following conditions: dough height, 0.8 cm; dough diameter, 2.2 cm; compression weight, 100 g;

compression time, 25 sec; recovery time, 35 sec.

Statistical Analysis

The experiment was planned according to a completely randomized design with 10 replicates. The data were analyzed according to the above design, and the treatments were tested using Duncan's new multiple range test.

RESULTS AND DISCUSSION

Chemical and Rheological Characteristics of Flours

Flour A has low gluten, AWRC, and farinograph water absorption (Table II), indicating its soft nature and, hence, its suitability for biscuit preparation. Flours B and C have higher gluten, AWRC, and farinograph water absorption and could be characterized as medium-hard flours.

Optimization of Compression Weight

The compliance increased from 14.0 to 49.4% with an increase in the compression weight from 100 to 570 g (Fig. 2). The increase in percent compliance for every 100 g of increase in weight was more at a lower compression weight (10.6% per 100 g), and it gradually decreased (5.0% per 100 g) with higher compression weight. This confirms the nonlinear behavior of biscuit doughs. The elastic recovery also increased with increase in compression weight to 410 g. Further increase in the compression weight, however, showed a decreasing trend in elastic recovery.

TABLE I
Biscuit Formula

Ingredient	Quantity (g)
Flour	100.0
Sugar	35.0
Shortening	20.0
Water	Variable
Sodium chloride	1.0
Sodium bicarbonate	0.5
Ammonium bicarbonate	1.0
Baking powder	0.3

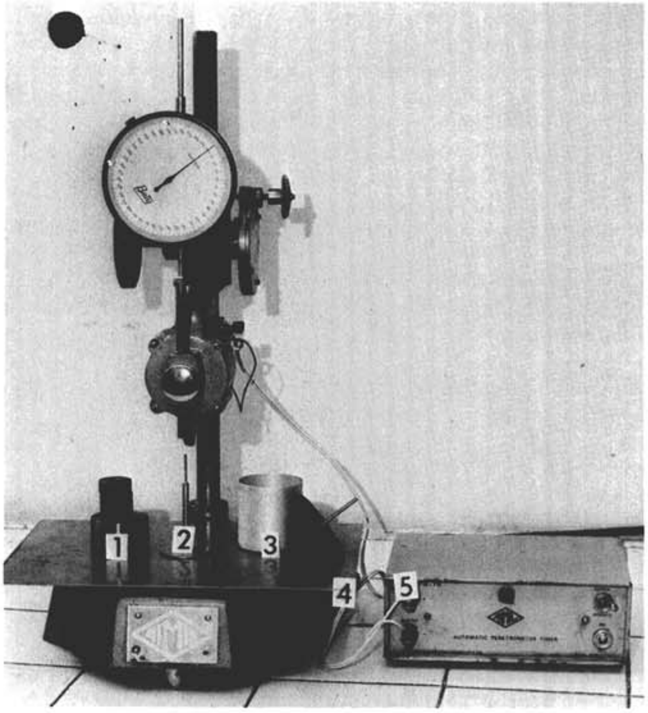

Fig. 1. Penetrometer with compression weights (1), compression plate (2), cup and cone (3), flat plate (4), and automatic timer (5).

The results indicated that the compression weight of 410 g was optimum for measuring the compliance and elastic recovery of biscuit doughs.

Effect of Water

Preliminary studies indicated that 27, 28, and 28.5% of water was required for flours A–C, respectively, to obtain desired dough consistency for preparing biscuits. The extrusion time of such doughs measured with a research water absorption meter ranged from 55 to 65 sec. This consistency was found to be optimum for biscuit doughs (Chandrashekara et al 1986). The compliance values depended on the quality of flour, and they were higher for soft wheat flour (A) than for the medium-hard wheat flours (B and C) (Table III). Increase of 2% water in the dough increased compliance values by 6.0–8.0% (Fig. 3 and Table III). The elastic recovery of biscuit doughs with varying levels of water (Fig. 3 and Table IV) showed an increase with increase in water. At any level of water, the elastic recovery was more and compliance was less for medium-hard wheat flours (B and C) as compared with elastic recovery and compliance for soft wheat flour (A).

Effect of Mixing Time

The compliance as well as the elastic recovery also depended on mixing time (Fig. 4 and Tables III and IV). Compliance in-

TABLE II
Chemical and Rheological Characteristics of Flour Samples[a]

Characteristics	Flour Sample A	B	C
Physicochemical			
Moisture, %	13.4	12.5	12.5
Gluten, %	7.0	9.0	9.8
Kent-Jones color grade value	1.0	2.3	2.5
Ash, %	0.34	0.47	0.49
Alkaline water retention capacity	56.0	60.0	60.0
Sedimentation value, ml	19.5	23.0	27.0
Falling number	450.0	478.0	560.0
Rheological			
Water absorption, %	54.4	58.6	57.6
Dough development time, min	1.5	2.5	3.0
Stability, min	2.5	4.0	5.0
Mixing tolerance index, BU	70	50	40
Resistance to extension, BU	370	360	600
Extensibility, mm	130	165	168
Area, cm^2	69.5	82.0	138

[a] Values are expressed on 14% moisture basis.

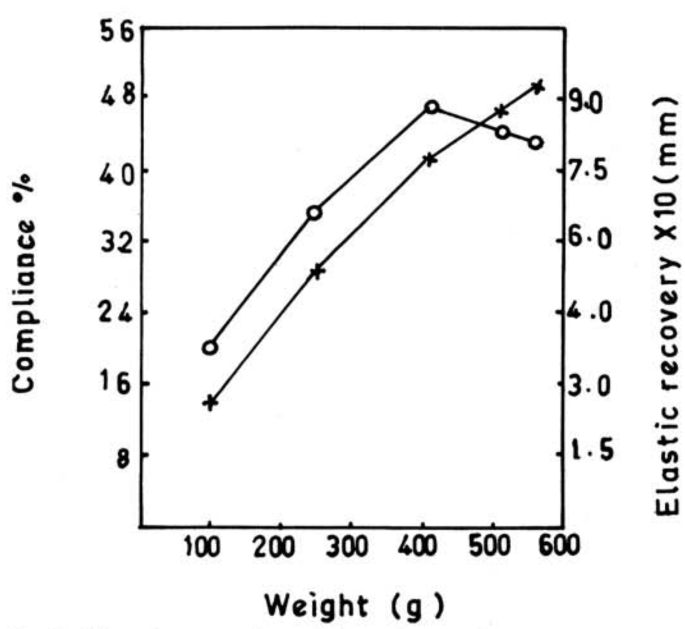

Fig. 2. Effect of compression weight on the compliance (×) and elastic recovery (O) of biscuit dough.

creased with increase in the mixing period in all of the flours. In general, it was also observed that the increase in compliance was 3.0% when the mixing period was increased from 2 to 3 min and 6.0% when mixing time was increased from 3 to 4 min. The higher increase in compliance could be attributed to the fact that first 3 min of mixing was required for the distribution of ingredients and hydration. Further mixing helps in the development of dough. The elastic recovery also increased with increase in mixing period and made the dough less suitable for molding because of its tendency to shrink. The increase in elastic recovery for an additional 1 min of mixing for different flours ranged from 0.65 to 1.13%. It is well known that for a short dough biscuit, the development of the dough should be minimum for better machinability and texture of biscuits. Elastic recovery was found to be more at any mixing period for medium-hard flours than for soft flour.

Interrelationship Between Water Level and Mixing Periods

The mixing periods have less effect on compliance at a lower level of water than at a higher level (Table III). Soft wheat flour showed a more significant effect even at a lower level of water compared with medium-hard wheat flours. The percent increase in the compliance values was 3.7 and 7.3% for medium-hard flours (flours B and C) and 10.6 for soft wheat flour (flour A). The greater effect on compliance of soft wheat flour biscuit dough is attributed to its lower water requirement. Similar trends were also observed at higher water levels. However, with increase in water, the extent of increase in the compliance for different flours remained about 14–17% at all mixing periods.

Elastic recovery values also increased with mixing period and water level. At a lower level of water, an increase in mixing period increased the elastic recovery considerably for all of the flours. However, with a higher level of water (30%) the effect was found to be less, and in most cases it was insignificant. It was interesting to note that a slight decrease in elastic recovery was observed when dough containing 30% water was mixed for a longer period of 4 min. This again indicated that the mixing time and water level are interrelated. With more water, less mixing period was required for the preparation of the biscuit dough and vice versa.

The compliance or elastic recovery values were not considerably

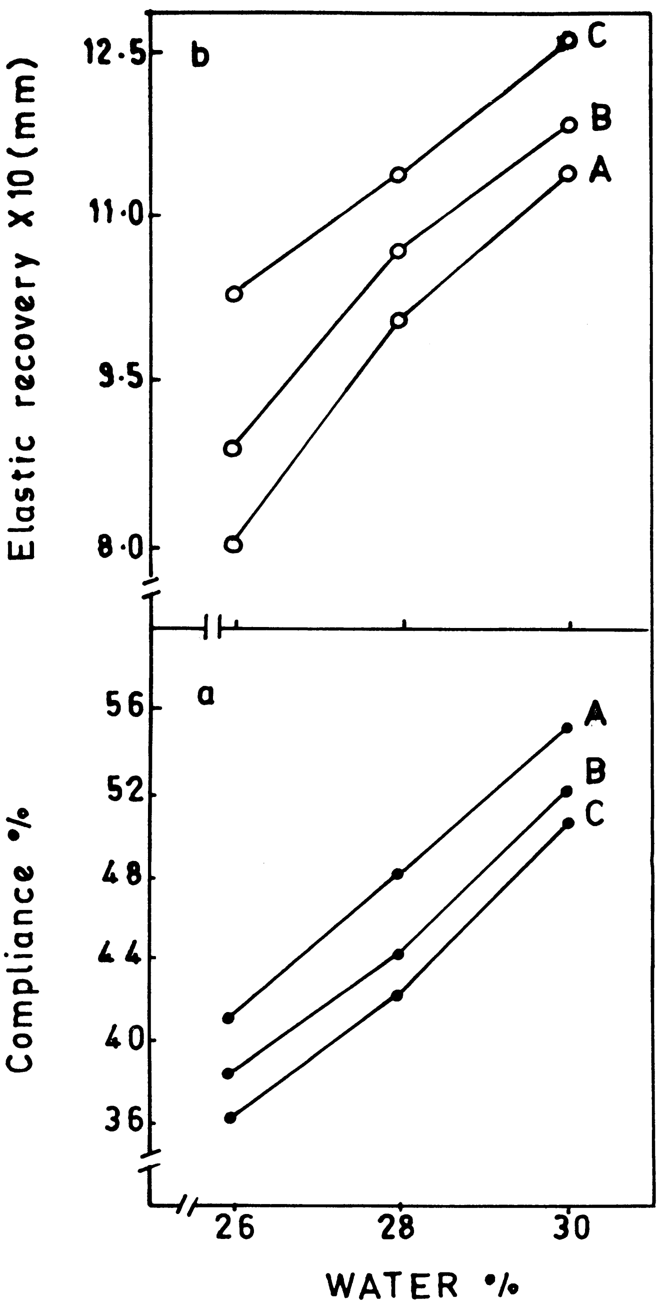

Fig. 3. Effect of different levels of water on the compliance (**a**) and elastic recovery (**b**) of biscuit dough mixed for 3 min. A, soft wheat flour; B and C, medium-hard wheat flours.

TABLE III
Effect of Water and Mixing Period on Compliance of Biscuit Dough[a]

Mixing Period (min)	Water, ml		
	26	28	30
Flour A			
2	34.65 a	45.18 b	47.38 c
3	41.07 d	48.22 c	55.20 e
4	45.27 b	54.38 e	60.29 f
SEM[b]			± 0.47
Flour B			
2	31.39 a	39.99 b	47.25 c
3	38.45 d	44.28 d	52.24 e
4	38.68 b	49.05 f	55.20 g
SEM[b]			± 0.39
Flour C			
2	35.66 a	40.57 b	49.01 c
3	36.13 a	42.34 b	50.97 e
4	39.36 f	47.96 c	56.85 g
SEM[b]			± 0.36

[a] Values for a particular flour followed by different letters differ significantly ($P \leq 0.05$) according to Duncan's new multiple range test.
[b] Standard error of the mean at 81 degrees of freedom.

TABLE IV
Effect of Water and Mixing Period on Elastic Recovery of Biscuit Dough[a]

Mixing Period (min)	Water, ml		
	26	28	30
Flour A			
2	6.88 a	9.70 b	10.06 b
3	8.05 c	10.02 b	11.38 d
4	9.67 b	11.06 d	10.91 d
SEM[b]			± 0.27
Flour B			
2	7.7 a	9.95 bc	10.97 bd
3	8.9 e	10.7 d	11.8 f
4	9.75 c	11.35 df	11.7 f
SEM[b]			± 0.25
Flour C			
2	9.0 a	10.27 b	11.52 c
3	10.27 b	11.33 c	12.56 d
4	11.95 cd	12.46 d	11.47 c
SEM[b]			± 0.30

[a] Values for a particular flour followed by different letters differ significantly ($P \leq 0.05$) according to Duncan's new multiple range test.
[b] Standard error of the mean at 81 degrees of freedom.

different in dough containing 26% water mixed for 4 min or with 28% water mixed for 2 min.

Biscuit Dough Characteristics Using the Viscoelastograph

The values obtained for compliance as well as for elastic recovery in the viscoelastograph corresponding to those measured with the penetrometer are given in Figures 5 and 6. Because the weight of dough, compression weight, and recovery time used were different for the above instruments, the absolute values obtained were also different. The compliance values obtained in the viscoelastograph were lower because of the lower compression weight used, and the elastic recovery was lower because the compressed dough has to lift the compression plate. The compliance measured with the penetrometer was significantly related to that measured in viscoelastograph ($r = 0.87$, $P < 0.01$). The regression equation to calculate the compliance (Y) in penetrometer was $Y = 22.22 + 1.654X$, where X is the compliance measured in the viscoelastograph. Similarly, elastic recovery measured by the penetrometer was found to be significantly correlated to that measured

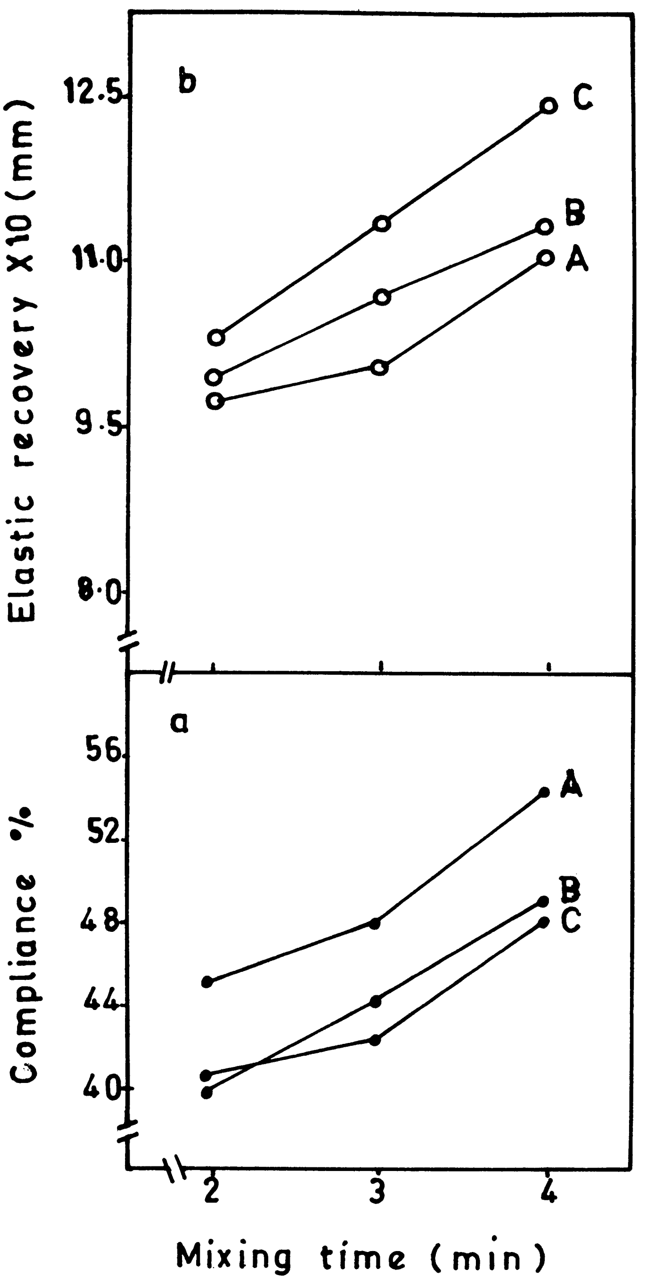

Fig. 4. Effect of mixing time on the compliance (**a**) and elastic recovery (**b**) of biscuit dough containing 28% water. A, soft wheat flour; B and C, medium-hard wheat flours.

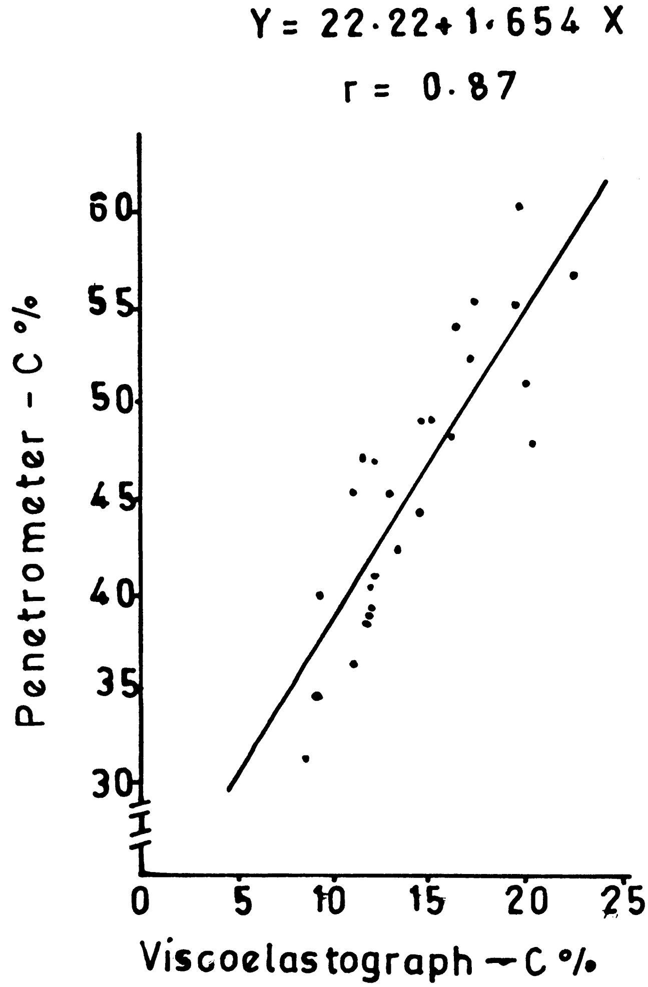

Fig. 5. Interrelationship between compliance (C) measured in the viscoelastograph and the penetrometer.

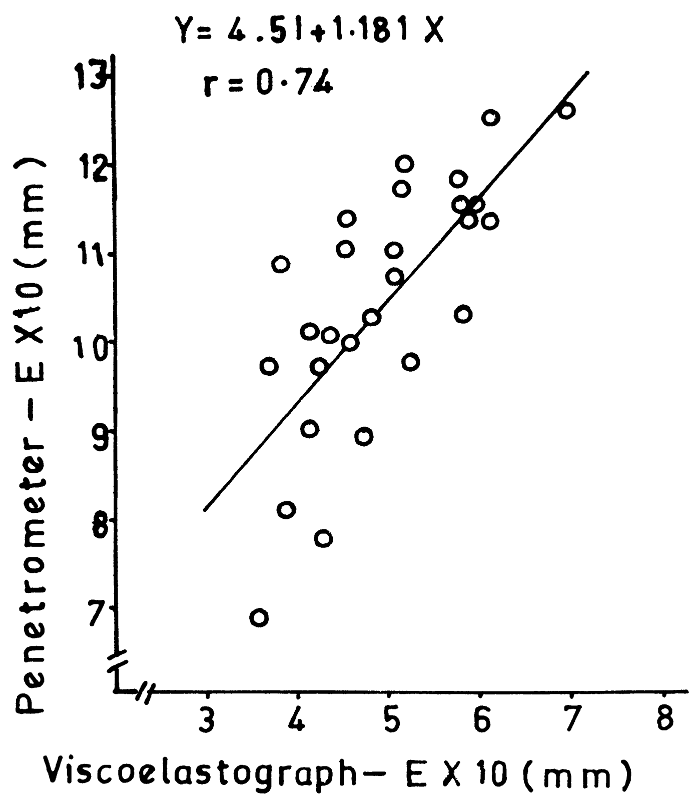

Fig. 6. Interrelationship between elastic recovery (E) measured in the viscoelastograph and the penetrometer.

in viscoelastograph ($r = 0.74$, $P < 0.01$). The regression equation to calculate the elastic recovery (Y) in penetrometer was $Y = 4.51 + 1.181X$, where X is the elastic recovery in viscoelastograph.

The above results are as expected: Compliance and elastic recovery of biscuit doughs are considerably affected by mixing period as well as by water level. The studies showed that a simple penetrometer with slight modification could be effectively used for measuring some of the rheological characteristics of biscuit doughs.

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