A New Instrument for Measuring the Breaking Strength of Jellies

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INTRODUCTION

Several instruments have been described in the literature for measuring the firmness of jelly. (1, 2)[2] Some of these measure firmness without exceeding the elastic limit of the jellies; others measure the breaking strength of the jellies (3). In the past there has been considerable disagreement as to the characteristics that should be measured in test jellies. Recently it has been advocated that both the rigidity and breaking strengths be measured when grading pectins (4). While both the Exchange Ridgelimeter developed at the California Fruit Growers Exchange and the Rigidometer developed at the Western Utilization Research Branch, USDA, are fairly satisfactory for measuring rigidity, the Tarr and Baker Tester, which is almost exclusively used for determining breaking strength, is not altogether satisfactory. The difficulties presented by the inability to apply a uniform pressure and the effect of the skin formed on top of the jellies have not been obviated.

The breaking strength of jellies is a more important characteristic from the preserver's point of view than the rigidity. The manufacturer of jellies is more interested in knowing how well his jellies will stand rough handling in shipping to distant points and how well a portion of jelly will spread over a piece of toast, cake, etc. For control work, the simplicity and reproducibility of a method are very important assets.

A torsional viscometer with a special attachment which lowers the rotating spindle into the material at a uniform rate has been found very convenient for measuring the breaking strength of jellies. The drag produced upon a spindle rotating at a definite constant speed while immersed in the jelly is recorded. At the same time, the spindle rotates as it is lowered into the body of the jelly. The torque required to turn the spindle as it constantly encounters new material is indicated on the dial of the viscometer. Since jellies are non-Newtonian in rheological properties the instrument will not give a true viscosity, but really a viscosity at a rate of shear which depends on such factors as the size of the spindle, the velocity of the rotating shaft, and the temperature. The instrument can be used at four different speeds and there are six different spindles for various ranges of viscosities of the

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[2] Numbers in parentheses refer to Literature Cited, p. 100.

materials examined.[3] Figure 1 shows the instrument assembled for use, and figure 2 the set of spindles which come with the instrument.

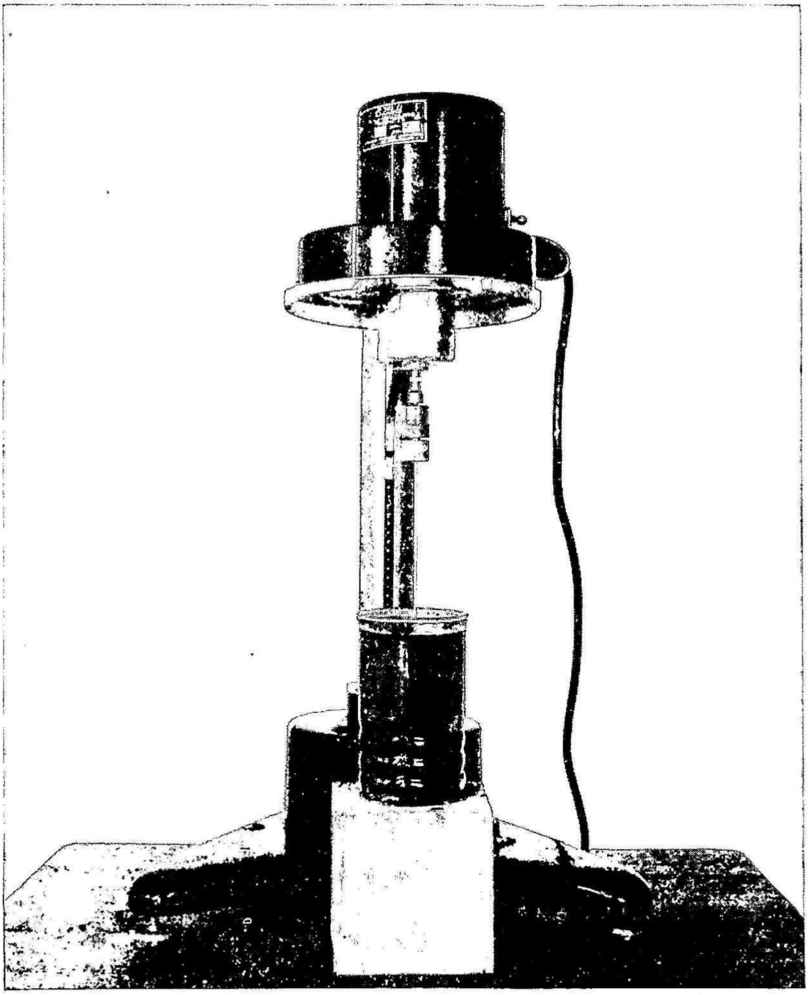

FIG. 1.—Torsional viscometer of the type used in this study.

EXPERIMENTAL PROCEDURES

The first step in the testing of the instrument consisted in selecting the most convenient speed and spindle to be used in the measurement of jelly strength. A guava jelly pronounced of excellent firmness by a panel of ex-

[3] The instrument used in these studies is manufactured by Brookfield Engineering Laboratories, Inc., Stoughton, Mass. It is calibrated in two scales: 100-unit and 500-unit.

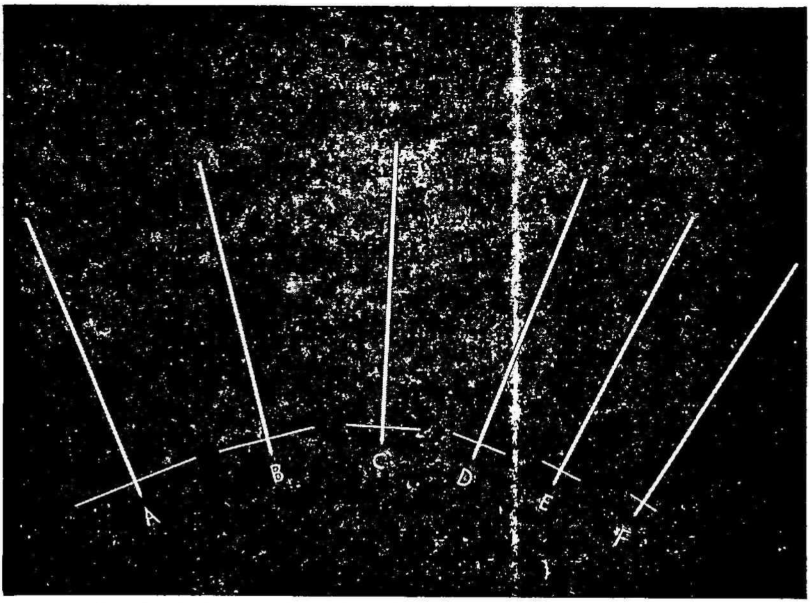

FIG. 2.—Set of spindles used: A, Spindle A; B, Spindle B; C, spindle C; D, spindle D; E, spindle E; F, spindle F.

TABLE 1.—*Readings of the viscometer and approximate viscosities in centipoises*[1]

Spindle	Velocity	Viscometer readings	Average reading	Average
	R.p.m.			*Centipoises*
C	1	45.0, 37.5, 38.0	40.2	804,000
C	2	60.0, 59.0, 52.0, 52.0, 43.0, 43.0	51.5	490,000
C	5	70.0, 65.0, 70.0, 65.0, 65.0, 67.0, 60.0 60.0	65.3	261,200
C	10	—	—	—
D	1	18.0, 15.0, 18.0	17.0	680,000
D	2	25.0, 23.0 24.0 25.0, 25.0, 25.0	24.5	490,000
D	5	40.0, 40.0, 38.0, 38.0, 35.0, 35.0, 35.0 37.0	37.3	298,400
D	10	—	—	—
E	1	12.0, 10.0, 10.0	10.7	1,070,000
E	2	15.0, 12.0, 12.0, 12.0, 12.0, 12.0	12.5	625,000
E	5	17.0, 17.0, 18.0, 18.0, 15.0, 15.0, 15.0, 16.0	16.4	328,000
E	10	—	—	—
F	1	3.5, 3.0, 3.0	3.3	660,000
F	2	7.0, 5.5, 7.0, 5.0, 6.0, 5.0	5.9	590,000
F	5	9.0, 7.0, 9.0, 9.0, 7.0, 8.0, 9.0, 8.0	8.3	332,000
F	10	—	—	—

[1] Measurements were made at approximately 28°C. and readings are on the 100-unit scale.

aminers was selected to be tested using all four velocities and six spindles. Spindles A and B were eliminated by inspection because the crosspieces

TABLE 2.—*Reproducibility of the method of measuring jelly strength using spindle C, velocity 1 r.p.m., 28°C.*

Container No.	Viscometer readings	Average
1	42.0, 28.0, 31.0	33.9
2	36.0, 29.0, 32.0	32.3
3	38.5, 29.0, 30.0	32.5
4	37.5, 30.0, 32.5	33.3
5	43.0, 29.0, 30.0	34.0
6	35.0, 33.0, 26.5	31.5
Mean		32.92
Standard deviation		.98
Standard error		.40
Coefficient of variation		2.98 percent

TABLE 3.—*Readings of the viscometer when used on jellies in different types of containers*

Type of container	Viscometer readings	Average
6-oz. Hazel Atlas jars	1: 35.0, 27.5, 31.2	31.2
	2: 24.0, 25.0, 35.0	28.0
9-oz. screw-cap jars	1: 38.0, 27.0, 25.0	30.0
	2: 35.5, 27.5, 27.0	30.0
6-oz. tumblers with pressure caps	1: 28.0, 34.0, 40.0	34.0
	2: 24.0, 35.0, 31.0	30.0
12-oz. tumblers with pressure caps	1: 38.0, 27.5, 25.0	30.2
	2: 37.0, 28.0, 27.0	30.7
12-oz. tall jars with aluminum screw caps	1: 36.0, 28.0, 24.0	29.3
	2: 38.0, 28.0, 28.0	31.3
Mean		30.47
Standard deviation		1.56
Standard error		.49
Coefficient of variation		5.09 percent

were considered too long (48 mm. and 36 mm. respectively) to be used in small jelly jars. Spindles C, D, E, and F were used with velocities 1, 2, 5, and 10 revolutions per minute. The data obtained are presented in table 1.

Approximate viscosity values are given in centipoises. These values were calculated from the calibration values given in a table supplied with the instrument.

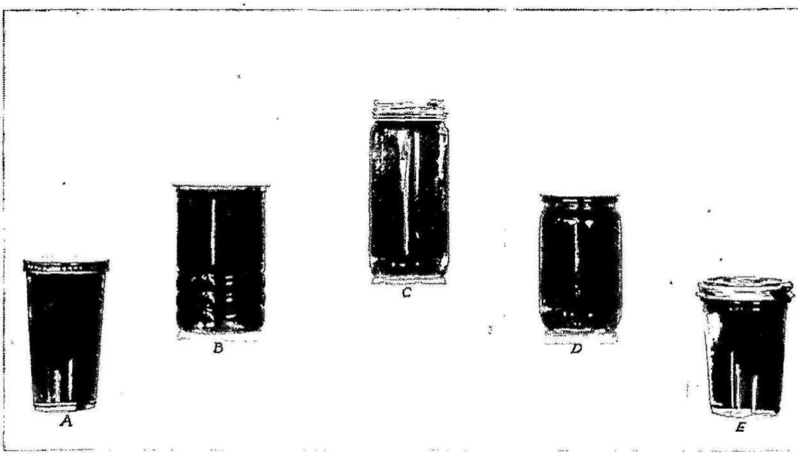

FIG. 3.—Types of jelly jars used in this work: A, 6-oz. tumbler with pressure cap; B, 12-oz. tumbler with pressure cap; C, 12-oz. tall jar with aluminum screw cap; D, 9-oz. screw-cap jar; E, 6-oz. Hazel Atlas jar.

TABLE 4.—*Comparison between values of jelly strength obtained by the torsional viscometer and the Delaware jelly strength tester*

Sample No.	Delaware instrument	Brookfield instrument
1	17.0	7.3
2	20.0	10.8
3	25.0	15.0
4	38.0	23.5
5	40.0	25.0
6	49.0	29.0
7	50.0	28.5
8	53.0	35.0
9	75.0	45.0

The reproducibility of the selected method of measuring jelly strength was tested by taking readings in six different jars of the same type containing jelly from a single batch. Results are presented in table 2.

The effect of size and shape of the containers, ranging from 6-ounce to 12-ounce jars was studied by pouring jelly of one batch into the following containers: 6-ounce Hazel Atlas jars, 6-ounce tumblers with pressure caps, 9-ounce jars with screw caps, 12-ounce tall jars with screw aluminum caps, and 12-ounce tumblers with pressure caps. The data are given in table 3. Figure 3 shows the type of jars used for the above work.

The jelly strength of a series of jellies was determined both by the torsional viscometer and Tarr and Baker's Delaware jelly strength tester. Table 4 presents values obtained with both instruments. Figure 4 shows the relation between them.

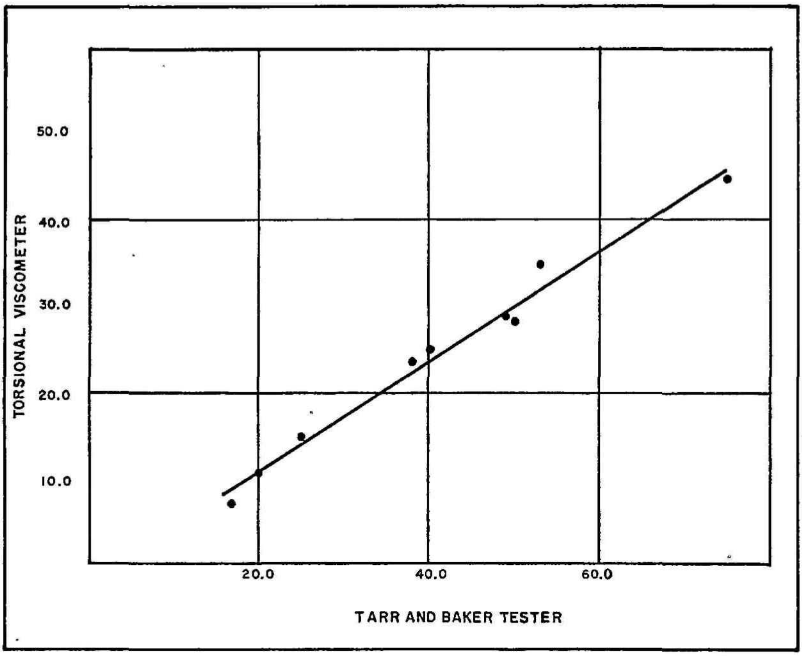

FIG. 4.—Relation between values of jelly strength measured with the viscometer and with the Tarr and Baker Delaware Jelly Strength Tester.

RESULTS AND DISCUSSION

From the data presented in table 1 it is evident that, since the jelly tested was of optimum firmness, the values obtained using spindle D at 1 and 2 revolutions per minute, spindle E at 1, 2, and 5 revolutions per minute, and spindle F at 1, 2, and 5 revolutions per minute were not convenient to use. It is desirable that a jelly of good firmness should read around 40 to 60 units so that the more tender and the tougher jellies will give satisfactory readings. Values for 10 revolutions per minute were not included because they were very erratic. It is not possible for the indicator needle to come to equilibrium at high speeds.

Good values were obtained using spindle C at 1, 2, and 5 revolutions per minute and spindle D at 5 revolutions per minute. Spindle C was chosen over spindle D because it gave slightly higher values. The lowest speed was selected since the literature accompanying the instrument said that low speeds were preferable for such materials as jellies, because the pitch of the helical path described by the crosspiece as it is lowered into the jelly is greatest at the lowest speed.

The reproducibility of the method of measurement using spindle C at 1 revolution per minute is shown in table 2. The values are expressed as instrument readings rather than in centipoises because the calibration of the spindle ranges in centipoises is approximate. The first reading is usually the highest and quite different from the others taken from the same jar. This discrepancy in the first reading may be due, in part, to inability of the instrument to reach equilibrium before the first reading is taken and, in part, to a skin effect which is noticeable only at the top of the jelly. After the instrument reaches equilibrium the readings are fairly uniform. Measurements should be made in jars which allow at least three readings to be taken so as to minimize the influence of the first reading. The agreement between averages of three readings per jar is excellent. The measurement of jelly strength should always be determined by using duplicate jars and making at least three readings per jar.

The effect of size and shape of container is presented in table 3. It can be seen that capacity of containers from 6 to 12 ounces does not appreciably affect the values for jelly strength as measured with the viscometer. Although the variation is greater than when measurements are made in the same type of jar, it is still acceptable. When the diameter of the jars is not uniform, but diminishes toward the bottom, as in the case of both 6-ounce containers, the last readings usually increase. It is preferable to use containers of uniform diameter so as to get more uniform values.

The data in table 4 and figure 4 show the relation between the values obtained using the Delaware tester and the viscometer. Values around 50 to 60 units on the Delaware tester correspond to values of about 30 to 40 units on the viscometer. Tarr and Baker considered strengths of 50 to 60 cms. of water excellent as determined by their instrument. It has been found that jellies of optimum firmness give values of about 40 units in the type of viscometer used in our study.

The described method of measurement has a number of advantages over other methods of measuring the breaking strength of jellies. The skin effect is not important since readings are taken in at least three levels of the column of jelly. The rate of applying the shear is uniform when the same velocity is used throughout the measurements. The radius of the helical path described by the crosspiece as it is lowered into the column of jelly is constant when a definite spindle is used. It is not necessary to remove the jellies from their containers and any inexperienced operator can make the measurements in any control laboratory. The reproducibility of the values is higher than that of the values obtained by the use of the Delaware tester.

SUMMARY

1. A torsional viscometer with a special device to lower the spindle of the instrument as it rotates has been used to determine the breaking strength of jellies and has been found excellent as to reproducibility of values obtained and simplicity of operation.

2. Values obtained by use of the tested viscometer are compared with corresponding ones obtained by the use of Tarr and Baker's Delaware jelly strength tester.

3. A torsional viscometer with a special attachment as described in this work is strongly recommended for control laboratories in the preserve industry. It is suggested that it be adopted for measuring the breaking strength of test jellies made to determine the jelly grade of pectins. A calibration curve can be prepared using a standard pectin and grades of tested pectins can be determined from such a curve.

RESUMEN

1. Un viscómetro de torsión con un dispositivo especial para bajar el eje del instrumento a medida que éste va girando, se ha encontrado de excelente reproducibilidad y facilidad de manejo, cuando se usa para determinar la dureza de cristales de guayaba.

2. Los valores obtenidos por el uso de este viscómetro se han comparado con los valores correspondientes obtenidos por el uso del instrumento desarrollado por Tarr y Baker en la Estación Experimental de Delaware.

3. El viscómetro de torsión descrito en este trabajo se recomienda para la determinación de dureza de cristales en laboratorios de control de la industria de conservas y para determinar la dureza de cristales preparados para determinar el grado de las pectinas usadas. Una curva de calibración puede prepararse utilizando una pectina standard y de dicha curva puede determinarse el grado de las pectinas examinadas.

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