Methods Employed In Expressing the Consistency of Plasticized Shortenings *

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The purpose of this paper is to describe methods used in the industry to determine the consistency, or as it is more frequently termed, the plasticity of shortening. In attempting this it seemed advisable to divide the paper into two sections; the first consists of some introductory remarks and the second the actual description of methods.

(I) INTRODUCTORY REMARKS

(A) Definition of the Term "Plasticity"

Before discussing the subject, it is necessary to make clear what is meant by "plasticity." As used in this paper, it shall mean the degree of pliability or the capability of a shortening to become molded or worked. A synonym which might be used is "ductility."

Plasticity must be distinguished from "texture" which refers to the physical structure of the constituent particles comprising the body of the fat or its surface. For example, when we call a shortening "stiff" we are referring to its plasticity. When we say it has a "high gloss" or is "grainy," we are talking about texture and so on.

The necessity for these simple definitions may appear obscure at first consideration, yet without an understanding of them, much confusion may arise.

(B) Essentials of an Acceptable Plasticity Method

In a practical sense, the goal of a plasticity method is to express by some simple, concrete term, the degree of workability of the shortening from the bakers' standpoint or from the standpoint of the housewife. As pointed out previously, it does not attempt to measure the smoothness, grain, gloss or any of the properties which are included under the classification of "texture."

Such a test necessarily must be an arbitrary one and therefore must be attended by all the severe conditions under which an arbitrary method is carried out. Unless this is done, the method fails.

It likewise is subject to all the interpretative weaknesses of this class of methods, for example limitation of scope resulting from the harsh restrictions imposed. Perhaps a good illustration is the Schaal Test for keeping quality. The result from that method represents stability but only under the test conditions. Transposition of the figure to shelf life is a difficult and involved matter.

Furthermore, the sample to be tested must be representative of the product. This may sound like a trite and somewhat threadbare statement which has been heard a good many times and yet it has particular significance in connection with plasticity measurement.

To illustrate, assume one wished to determine the stiffness of a product that was packed in a drum. Assume also that the method did not permit testing the product in this manner, only a small can of sample being used in the instrument employed.

This would necessitate a transfer of the product from the drum to the proper-sized can with a possibility that its plasticity is altered in the operation. Two possible causes of this are unintentional working and air incorporation. These may appear to be inconsequential but experience has demonstrated their importance.

A third requirement of a successful plasticity method, and perhaps the most fundamentally essential of all, is that it actually measures plasticity. Obviously this is a large order and requires extended study and development. The method of course must also be accurate and give reproducible results.

(C) Existing Conditions in the Industry

The subject of plasticity is rather an unusual one from a number of angles. One is the lack of a standard method today. Great importance is attached to the familiar chemical tests employed in controlling quality or the physical status of a shortening. Among these are the Iodine Number, Thiocyanogen Number, Congealing Point, Wiley Melting Point, Free Fatty Acid and the Color. The chemist utilizes them not alone in the finished product but likewise as a control measure on the product, or its ingredients, during the various stages of manufacture.

Many of the tests are employed specifically for the purpose of attaining a uniform plasticity in the finished product. It has been established by experience, for example, that the Iodine Number, the Congealing Point and the Wiley Melting Point influence the property to a marked extent. As a result, the chemist relies heavily upon them for guidance.

However, there are factors other than the chemical tests which affect plasticity. To name two of them—the conditions under which a shortening is plasticized and the conditions under which it is tempered subsequent to filling. It follows that a reliable, rapid method for determining plasticity, and expressing it in some simple, concrete term, is highly desirable. In effect, such procedure would function as the final yardstick in expressing the plasticity. It would represent the culmination of all the careful control conducted during manufacture in maintaining the proper chemical and physical constants.

A survey of the industry revealed the complete absence of anything approaching standardization in this respect. It is true that some ideas were found but they were most strikingly characterized by their diversity.

Some laboratories did not employ any procedure whatever except the ancient "finger method." In some quarters considerable skepticism existed that a suitable method is possible or is even desirable.

At any rate I will attempt to present in a brief manner the various methods which were outlined to

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me through the courtesy of the officials of the laboratories which use them. In doing this no effort will be made to favor or develop one over another. The description is intended to convey only the facts.

(II) Description of Methods

One company drops a metal needle-like cone from a point 14 inches above the surface of the sample and records the depth of penetration as a measure of the plasticity. Of course the greater the extent of penetration, the softer the sample and vice versa. The test is carried out at a temperature of 70°F, both cone and sample being at this level. It is essential for the cone to be fixed in size, weight and smoothness and these are carefully maintained. The cone is approximately six inches in length and five-eighths of an inch in diameter at the wide end. From this size it gradually tapers to a point in its six-inch length.

Reproducible results are claimed and it does not take long to operate. Another advantage is the relatively low cost of the apparatus, in contrast to some of the other consistometer instruments used.

The Bloom Consistency Tester is a device which is used by some laboratories. In brief, it consists of a hollow cylindrical ring attached to a plunger that works in and out of a second cylinder. Fastened to the end of the second cylinder is a gage which registers any pressure exerted upon the lower or first cylinder. A non-compressible liquid such as glycerine fills the bore of the second cylinder between the plunger and the gage.

In operation, the instrument is pushed into the sample with a steady, easy motion. The maximum pressure is reached when the product starts coming through the lower cylinder and is recorded as a measure of the plasticity.

Another company employs a penetrometer somewhat similar to the A.S.T.M. grease penetrometer. It consists of an adjustable scale and "needle" supported by a ring stand. The "needle" is really a small cone fastened to a shaft, the assembly weighing close to 160 grams. It is kept in place by a spring-stop which can be released by pressure of the finger.

A scale is located above this so-called needle. It is marked off in angular degrees. Passing through the back of the scale and reaching down to the needle is a movable geared rod, which revolves the pointer around the face of the scale. In other words as the "needle" is lowered into the sample the scale reading increases. If it drops 35 centimeters, for example, a complete revolution of 360° is recorded.

All the tests are made at a definite temperature. The sample is placed below the needle and the surface is scraped even. The needle is then set up at a point exactly 35 centimeters (or 360° on the scale) above the surface. Next, the stop is released which allows the needle to fall. It drops, of course, 35 centimeters (or one scale revolution) through the air before sinking into the surface of the shortening. The penetration is reported as the scale reading corresponding to the drop into the shortening and does not include the distance traversed through the air.

Tests are conducted at temperatures ranging from 40°F to 95°F in order to determine the "plastic range" or degree of relative softness at the low temperature and relative firmness at the high temperature. Needless to relate, the best products in this respect are those which are softest at the low temperature and are also firmest at the high temperature. A perfect plastic range, if it existed, would have the same plasticity at both temperatures, providing that the degree of plasticity is good.

There is one laboratory which has developed a procedure to use not on the finished plasticized product but on the product in the course of hydrogenation. It gives a clue as to actual body characteristics to expect on the finished product hence is worthy of mention.

A hexagonal metal block is drilled with a ¼-inch hole to a depth of 40 millimeters. This is located in its center and holds the sample which is poured in melted. The block with samples is then chilled overnight at 40°F. Next morning, it is placed in a constant temperature both at 70°F, or at whatever temperature it is desired to make the test. After two hours in the bath the test is made.

The apparatus in the center consists of another hexagonal block which holds a glass tube with a bore of small diameter. The latter is approximately seven mm in outside diameter and 22 cm. in length. Behind the tube is a scale graduated in millimeters. The needle is about 61 mm long and weighs 0.43 gram and the scale is adjusted with its top edge even with the top of the needle when the point of the latter is at the base of the block.

In testing, the apparatus in the center of the slide is placed on top of the sample block and the needle is dropped through the glass tube. Results are tabulated in terms of the distance in tenths of a millimeter the needle sinks into the sample at the temperature the penetration was made.

The Armour Laboratory and several others measure plasticity using the A.S.T.M. grease penetrometer. This instrument expresses plasticity in terms of the depth to which a metal cone sinks into the surface of the sample under definite prescribed conditions. The figure thus is higher for soft fats and lower for harder ones.

The instrument has a cone of standard size and shape attached to a shaft, the two being released by a stop located directly in front of the gage. This latter measures the distance the cone and shaft penetrate the sample which is directly under it. The weight of cone and shaft is 150 grams and it is adjustable to a wide range of levels by a screw on the supporting stand in the back. Fine adjustment is facilitated by a mirror. Another feature is a levelling indicator which insures the cone and shaft are perpendicular.

Briefly, the test is made on the level surface of shortening in cans not over four pounds in size, this being the largest size that can be handled. While the details of the sampling procedure will not be presented I will mention that if the product to be tested is in a container larger than four pounds, a small sample is withdrawn from it by sinking a bottomless one-pound tin (i.e. a cylinder open at the ends) into the surface. It is actually sunk out of sight and then withdrawn, sample plug and all. After holding at 70°F overnight, the surfaces are sheared off quickly in order to avoid disturbing the fat as much as possible. The penetration test is now ready to be run on the smooth surface.

When the instrument has been set so that the cone tip is exactly at the surface, it is released to sink freely into the fat for five seconds. The distance which it drops in tenths of a millimeter is reported as the penetration at 70°F.

Many precautions must be observed which, if not taken care of properly, might influence the results. First, of course, are the precautions incident to sampling. However, these will not be given as they are too lengthy. Some of the precautions to observe in connection with the test itself are:

(1) The instrument must be set level or the cone will encounter friction in its drop and low penetrations will occur.

(2) The holes or "punches" must not be closer together than one inch or nearer than this from the edge of the can.

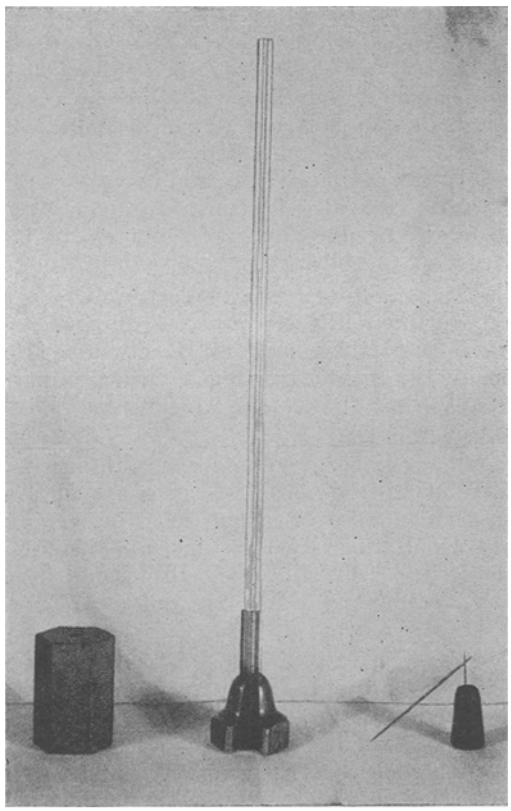

FIG. 1. Metal block, tube, and needle (used in penetration determination, described in text).

(3) The cone and shaft must be free from rust, grease or dirt.

(4) The temperature of penetrometer and samples must be 70°F.

(5) The can holding the sample must not rock on the penetrometer stand.

(6) The point of the cone must be set exactly at the fat surface. This is perhaps the greatest source of error between observers.

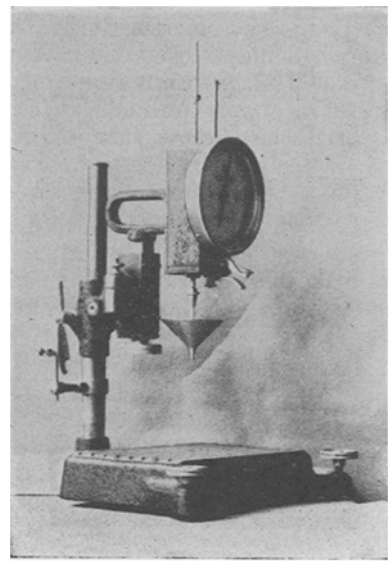

FIG. 2. A.S.T.M. grease penetrometer.

Table I shows the penetrations at 70°F on three samples cut from an eight-pound can, a fifty-pound can, a 100-pound can and a drum of the same shortening respectively. The latter happens to be of medium plasticity, namely about 165 penetration. Note that eight individual tests were made on each sample. The greatest deviation occurring was 8 points and the smallest 2. Average deviations varied from 0.7 to 2.3 points.

Table II gives the penetrations at 70°F on twelve 1-lb. cans filled in succession from the same tank of product. You will note first that this is a softer shortening than that in the previous slide, the grand average of all twelve samples being 195 against 165. The widest deviation on the sample was 9 points and the narrowest 2. The average deviation varied from 0.4 to 3.2 points.

TABLE I

Penetration at 70°F. on Shortening Filled Into Various Sized Large Containers and Cut Out

Individual Test No.	8-lb. Can Sample Number			50-lb. Can Sample Number			100-lb. Can Sample Number			385-lb. Drum Sample Number		
	1	2	3	1	2	3	1	2	3	1	2	3
1	161	161	160	164	167	166	165	165	162	168	166	166
2	161	161	159	164	166	169	162	164	163	167	168	166
3	161	161	160	161	167	166	168	163	164	167	167	164
4	159	163	162	164	164	168	168	163	167	167	166	166
5	159	159	162	169	164	167	170	161	165	167	167	163
6	158	165	162	163	166	167	165	164	168	167	169	167
7	161	163	160	165	165	171	167	164	167	168	170	168
8	158	162	161	164	167	167	170	168	168	169	169	164
High	161	165	162	169	167	171	170	168	168	169	170	168
Low	158	159	159	161	164	166	162	161	162	167	166	163
Devia.	3	6	3	8	3	5	8	7	6	2	4	5
Av. Dev.	1.2	1.4	1.0	1.2	1.0	1.3	2.3	1.2	2.0	0.7	1.2	1.2
Ind. Av.	160	162	161	164	166	168	167	164	166	168	168	166
Sample Av.	161			166			166			167		

Table III gives the results on a very hard shortening which was filled into six 1-lb. tins. Four collaborators made independent tests on these in order to determine the degree to which they could check each other. The collaborators averaged 87, 91, 88 and 88 respectively. Total deviations on individual samples varied from 3 to 8 points and average deviations varied from 0.5 to 1.6 points.

TABLE II

Penetrations at 70°F. on Shortening Filled Directly Into One-Pound Tins

Individual Test No.	Sample Number											
	1	2	3	4	5	6	7	8	9	10	11	12
1	193	195	197	192	191	191	196	196	198	196	196	197
2	194	196	192	195	192	190	197	197	201	197	198	198
3	191	189	199	195	195	189	197	198	198	198	197	198
4	194	195	192	198	195	192	200	195	199	198	195	199
5	197	198	190	197	195	192	199	196	200	198	197	198
High	197	198	199	198	195	192	200	198	201	198	198	199
Low	191	189	190	192	191	189	196	195	198	196	195	197
Deviation	6	9	9	6	4	3	4	3	3	2	3	2
Av. Devia.	1.4	2.0	3.2	1.6	1.8	1.0	1.4	0.8	1.2	0.8	0.8	0.4
Ind. Av.	194	195	194	195	193	191	198	196	199	197	197	198
Grand Av.	195											

A rather interesting feature which developed from the use of the penetrometer was the Plastic Range Index. To arrive at it, the penetration must be run at 98°F as well as at 70°F. The Index is then equal to this equation:

$$\text{P.R.I.} = 100 - \frac{\text{Penetration at 98F°} - \text{Penetration 70°F}}{10}$$

It is usually expressed as the figure derived from the equation · over the penetration at 70°F, such as $\frac{89}{165}$ or $\frac{72}{120}$. The reasons for this are explained later.

TABLE III

Penetration at 70°F. on Shortening Filled Directly Into One-Pound Tins

Individual Test No.	Collaborator A			Collaborators		
	Sample 1	Sample 2	Sample 3	B	C	D
1	89	87	90	92	88	88
2	87	86	90	91	87	88
3	86	84	88	94	89	87
4	87	83	87	91	86	87
5	87	85	88	90	86	85
6	88	86	89	90	94	87
7	87	88	88	91	89	88
8	87	86	88	90	88	91
High	89	88	90	94	94	91
Low	86	83	87	90	86	85
Deviation	3	5	3	4	8	6
Av. Devia.	0.5	1.1	0.7	0.9	1.6	1.1
Ind. Av.	87	86	88	91	88	88
Sample Av.	88					

The index is based upon the assumption that if a shortening has a penetration at 70°F within the limits of good plasticity, e.g. 140 to 180, the plastic range is better the closer is the penetration at 98°F to that at 70°F. In simple terms this means if a product has a normal plasticity at 70°F, the firmer it is at 98°F the wider the plastic range is.

Expressing it in terms of actual penetrations, if a product has a normal penetration of say 150 at 70°F, it has a better plastic range if the penetration at 98°F is 190 than if it is 320. The index of the 190 sample would be $^{9}6/_{150}$ and of the 320 sample $^{8}3/_{150}$. As mentioned before, perfection would be attained if a product has equal penetration at 70° and 98°F, the penetration of course lying in the approved zone of 140-180. In this case the index would be 100.

It was in order to avoid misleading results that the penetration at 70°F was included in the index. The underlying reasons are so obvious no attempt will be made to give illustrative examples.

Table IV lists a number of hydrogenated shortenings of various manufacturers with their indices. For the sake of clarity I did not give the index in its usual form, i.e. with the penetration at 70°F written in below. The latter of course is already given. You will note the indices range from 66 on sample E to 92 on sample C. Sample C has a good penetration at 70°F and yet the lowest penetration at 98°F which makes for the highest index. The penetration on E, however, was 112 at 70°, a figure which represents a rather firm product, and 450 at 98°F. The latter is very sloppy. In other words E has a narrow plastic range and C has a fairly wide one.

TABLE IV

Plastic Range Indices on a Series of Hydrogenated Shortenings of Different Manufacture

Shortening	Penetration at		Plastic Range Index
	70°F.	98°F.	
A	139	270	87
B	137	270	87
C	153	230	92
D	129	340	79
E	112	450	66
F	126	280	85
G	144	380	76
H	145	290	86
I	174	350	82
J	179	340	84

In concluding, I wish to say that I have attempted to describe some of the varied but few shortening plasticity methods being used in the industry today. I also wish to thank the individuals who submitted methods for their courtesy and cooperation.