12. U. S. Department of Agric., Bur. Agr. Econ., The Fats and Oil Situation, FOS-73, March 1943, p. 15.
13. F. R. Fosberg, Principal Economic Plants of Tropical America in "Plants and Plant Science of Latin America," ed. F. Verdoorn, Chronica Botanica, Waltham, Mass,, 1945, pp. 18-35.
14. V. Rogers, Abaca, Cacao, and the African Oil Palm in Costa Rica, Inst. of Inter-American Affairs, Special Report, 1947, 33 pp.
15. Anon., La Palma de Aceite, Dir. Gen. de Agr. de Guatemala, 1940, pp. 3-8.
16. W. Vogt, The Road to Survival, Sloane, New York, 1948, 359 pp.
17. M. L. Bomhard, Brazil's Oil-Yielding Palms, Agriculture in the Americas, Office of Foreign Agriculture Relations, U. S. Dept. of Agr., 6, No. 1, 6-9, 14-15 (1946).
18. C. Pesce, Oleaginosas da Amazonia, Belém-Para, 1941, 128 pp.
19. J. B. de M. Carvalho, O. Brasil e os Óleos Vegetais, Servico de Informação Agrícola, Ministério da Agricultura, Rio de Janeiro, 1942, 208 pp.
20. K. S. Markley, Fat and Oil Resources of Latin America in "Plants and Plant Science in Latin America," ed. Frans Verdoorn, Chronica Botanica, Waltham, Mass., 1945, pp. 211-218.
21. D. W. Jenkins, Use of the Airplane in Vegetation Surveys, Ecology, *26*, 413-414 (1945).
22. Anon., Bull. Imp. Institute, *17*, 186-189 (1919).
23. W. J. Blackie and G. R. Cowgill, Occurrence of Carotene in the Oil of *Attalea gomphococca* Mart. and Its Relation to Vitamin A Potency, Food Research, *4*, 129-133 (1939).

Testing of Drying Oils. III. Correlation of Evaluation Data*

G. W. HOUSTON, E. C. GALLAGHER, and DON S. BOLLEY, National Lead Company Research Laboratories, Brooklyn, New York

THE method used by the National Lead Company for the preliminary evaluation of drying oils has previously been described in detail (1) and the experimental data for a number of natural and synthetic oils has been published (2). Since the possible uses of drying oils are so varied, even a preliminary evaluation entails the gathering of a large amount of data. After even a few oils have been evaluated, the data are so voluminous as to be unwieldy. An accurate summary of the performance of one oil is difficult to obtain while comparisons between several oils are definitely cumbersome. Therefore, it became necessary to devise some method of presenting or summarizing the data which would permit the various oils to be compared rapidly if the evaluation results were to achieve their maximum usefulness.

It is not possible to group all the data together onto one large chart. This would simplify the problem only slightly since the chart would be much too large and complicated for easy reading and study. The method finally adopted therefore was to divide the performance of the oils under each test into groups and assign to each group a numerical value. The performance of an oil in all tests could then be summarized by a single number by the use of a suitable method of averaging.

One method of averaging or weighting is suggested here chiefly as an example. It is realized that the various weights assigned to each test are one of opinion and will vary with individuals, depending on their interests and their personal reliance on the particular test. Discussion and use of the weighting scheme would result in an optimum weighting factor of most general usefulness.

The tests performed under the evaluation program were divided into three groups: first, those performed on the oil; second, those performed on varnishes made from the oil; and third, those performed on paints made from the oil. Since the information gained from the oil tests is of a more fundamental character than that from the paint or varnish tests, it was given slightly more weight in making up the final average. The maximum number of points possible in each of the three groups of tests is:

Oil tests	40 points
Varnish tests	30 points
Paint tests	30 points

The final figure is then obtained by adding up the points scored in each group of tests.

The performance of an oil on an individual test is rated from 0 to 10, inclusive. This permits the classification of the oils into 11 divisions on each test although on some tests a smaller number of divisions is satisfactory. The relative importance of the individual tests is indicated by a factor by which the rating of the oil is multiplied in obtaining the group average. An asterisk is used in the charts to indicate the presence of some unusual factor. When it appears next to the rating of an oil on an individual test, it means the original experimental data should be consulted. An asterisk appearing with one of the weighted averages indicates something unusual in the method of computing the average. For instance, if an oil cannot be used in varnishes, the varnish tests are ignored entirely instead of being given a rating of zero, and the final average is attained by adding the points scored in the oil and paint tests, and then multiplying by a factor of 10/7, and an asterisk placed along side the final average. This is done because the oil would suffer a handicap if a rating of zero was given to the varnishes and its possible advantages as a paint vehicle might be overlooked entirely if only the total averages were considered.

In the following discussion, the tests and methods used in arriving at the weight factor and rating are discussed.

Oil Tests

Appearance—Weight Factor=0.4

Rating: Numerical values applied are 0, 3, 6, 10. The oil shall be bright and clear, have a light color (maximum of 10 Gardner), and not give more than a slight precipitate after 18 hours at 40°F. to earn a value of 10. The odor of the oil shall be normal.

Bodying Rate—Weight Factor=0.8

Rating for A to G viscosity oils:

Rating	Gel Time (minutes)
10	0 to 50
9	51 to 100
8	101 to 150
7	151 to 200
6	201 to 250
5	251 to 300
4	301 to 350
3	351 to 400
2	401 to 450
1	451 to 500
0	over 500

* Presented at 22nd annual fall meeting, American Oil Chemists' Society, Nov. 15-17, 1948, New York City.

TABLE I

Oil and Oil Film Tests

	Appearance	Bodying	Resin Compatibility	Drying	Hardness	Cold Water Resist.	Hot Water Resist.	Alkali Resist.	React. ZnO	Film Solub.	Weighted Figure
Factor	0.4	0.8	0.1	0.9	0.3	0.1	0.1	0.1	0.4	0.8	
G Bodied Linseed	6	5	1	6	6	9	7	6	8	5	23.1
Conjugated Linseed	10	7	1	7	3	1	2	2	10	1	22.2
Linseed Penta	10	8	2	8	3	1	1	1	10	8	22.9
Dehydrated Castor	10	8	3	8	1	0	1	2	10	0*	22.5
Fatty Tall Oil	6	0	0	5	4	2	0	10*	5	0	11.3
G Bodied Soybean	6	0	0	0	5	0	1	10	10	0*	9.0
Conjugated Soybean	10	1	1	0	5	0	9	10	10	0*	12.3
Soybean Penta	6	7	3	5	3	0	1	7	10	3	20.9
Soybean Mannitol	10	3	3	4	3	0	1	2	10	0*	15.5
Soybean Sorbitol	10	4	3	6	3	0	1	2	0*	0	14.1
Q Bodied Linseed	10	3	0	6	2	8	7	7	6	6	21.8
Linseed Polypenta	10	8	0	10	4	10	10	0	10	9	33.8
Linseed Mannitol	10	6	3	6	1	2	2	1	3	4	19.7
Linseed Sorbitol	10	6	1	8	3	0	1	2	0	7	22.9
Soybean Polypenta	10	6	0	8	4	10	9	0	10	9	30.3
Soybean Maleic Glyc	10	2	3	6	4	0	10	3	2	6	19.4
Soybean Maleic Penta	10	6	3	1	6	10	10	3	10	7	23.7
Z2 Bodied Linseed	10	2	0	6	5	8	8	7	1	6	20.0
Linseed Maleic Glyc	10	7	1	8	2	2	8	2	0	7	24.3
Linseed Maleic Penta	10	9	3	10	3	2	10	1	0	7	28.3

Q viscosity oils are graded in steps of 30 minutes each and Z2 viscosity oils are graded in steps of 15 minutes in a similar manner.

Resin Compatibility—Weight Factor=0.1

Rating	
0	Incompatible with all resins
1	Compatible with modified alkyd resin only
2	Compatible with any resin other than modified alkyd
3	Compatible with two resins
5	Compatible with three or more resins
10	Compatible with all resins

Drying Test—Weight Factor=0.9

Rating	
10	Set to touch in 1½ hours with good final dry
9	Set to touch in 2 hours with good final dry
8	Set to touch in 2½ hours with good final dry
....	..... etc. .....

A good final dry means that the film shall have a dryness rating of at least 9+ after 192 hours.

Hardness—Weight Factor=0.3

Rating is equivalent to the number of swings of the Sward Rocker on the film after drying 192 hours, 10 or more swings being rated as 10.

Cold Water Resistance—Weight Factor=0.1

Rating	
0	Fail in less than 24 hours
1	Fail in 24 hours
2	Fail in 48 hours
4	Fail in 72 hours
6	Fail in 96 hours
8	Fail in 120 hours
9	Fail in 164 hours
10	Fail in 192 hours

Hot Water Resistance—Weight Factor=0.1

Rating: 10=Pass. If the oil fails, give 1 point for each 5 minutes until whitening occurred up to a maximum of 9.

Alkali Resistance—Weight Factor=0.1

Rating: One point for each 5 minutes until failure.

Reactivity (zinc oxide)—Weight Factor=0.4

Rating: Ten minus one point for each 10% increase in consistency after one week.

Film Solubility—Weight Factor=0.8

Rating: Average the per cent solubility in acetone and alcohol-benzene.

TABLE II

Bakelite BR 254 Varnish Tests

	Cooking Time	Drying	Hardness	Kauri Red.	Cold Water Resist.	Hot Water Resist.	Alkali Resist.	Appearance	Weighted Figure
Factor	0.4	0.6	0.5	0.4	0.2	0.2	0.3	0.4	
G Bodied Linseed	3	8	7	10	10	8	2	7	20.5
Conjugated Linseed	4	3	3	10*	10	7	1	10	16.6
Linseed Penta	3	5	4	10	10	10	5	7	18.5
Dehydrated Castor	5	5	4	10*	10	10	3	5	17.9
Fatty Tall Oil	....	....	....	....	....	....	....	....	....
G Bodied Soybean	0	5	3	10	10	10	2	7	15.9
Conjugated Soybean	0	3	2	10	10	7	0	10	14.2
Soybean Penta	3	3	2	10*	10	10	3	7	15.7
Soybean Mannitol	1	5	4	10	8	10	1	10	17.3
Soybean Sorbitol	1	5	4	10	10	9	1	7	16.3
Q Bodied Linseed	2	4	4	10	10	10	0	10	17.2
Linseed Polypenta	8	8	5	10	10	7	10	7	23.7
Linseed Mannitol	4	8	8	9	10	10	1	7	21.1
Linseed Sorbitol	4	8	10	6	10	3	2	7	19.8
Soybean Polypenta	7	8	3	10	10	7	10	10	23.5
Soybean Maleic Glyc	2	5	5	10	8	7	0	10	17.3
Soybean Maleic Penta	7	3	7	7	10	10	1	7	18.0
Z2 Bodied Linseed	7	0	4	10	10	7	1	5	15.3
Linseed Maleic Glyc	....	....	....	....	....	....	....	....	....
Linseed Maleic Penta	....	....	....	....	....	....	....	....	....

TABLE III

Amberol 801 Varnish Tests

	Cooking Time	Drying	Hardness	Kauri Red.	Cold Water Resist.	Hot Water Resist.	Alkali Resist.	Appearance	Weighted Figure
Factor	0.4	0.6	0.5	0.4	0.2	0.2	0.3	0.4	
G Bodied Linseed	7	5	10	6	10	10	8	7	21.6
Conjugated Linseed	4	8	8	7	5	8	4	5	19.0
Linseed Penta	6	9	9	7	10	10	6	10	24.9
Dehydrated Castor	8	10	6	10	8	8	3	7	23.1
Fatty Tall Oil	....	....	....	....	....	....	....	....	....
G Bodied Soybean	3	3	4	10	10	9	6	5	14.6
Conjugated Soybean	4	3	3	10	5	7	7	5	15.4
Soybean Penta	6	6	7	6	10	3	10*	10	21.5
Soybean Mannitol	9	6	7	4	5	3	7	10	20.0
Soybean Sorbitol	5	6	8	4	5	8	5	10	19.3
Q Bodied Linseed	7	5	10	6	10	10	8	7	21.6
Linseed Polypenta	....	....	....	....	....	....	....	....	....
Linseed Mannitol	6	8	10	5	5	7	7	10	22.7
Linseed Sorbitol	6	8	10	1	10	2	6	7	19.6
Soybean Polypenta	....	....	....	....	....	....	....	....	....
Soybean Maleic Glyc	8	8	5	9	10	10	3	10	22.7
Soybean Maleic Penta	10	0	7	3	9	10	10	10	19.5
Z2 Bodied Linseed	7	5	10	6	10	10	8	7	21.6
Linseed Maleic Glyc	9	9	9	7	8	7	4	10	24.5
Linseed Maleic Penta	9	9	10	5	8	7	3	10	23.9

Rating	Per Cent
10	0 to 15
9	16 to 25
8	26 to 35
7	36 to 40
6	41 to 45
5	46 to 50
4	51 to 55
3	56 to 60
2	61 to 65
1	66 to 70
0	over 70

Varnish Tests

Cooking Time—Weight Factor=0.4

Rating	Minutes
10	0 to 15
9	16 to 30
8	31 to 45
7	46 to 60
6	61 to 75
5	76 to 90
4	91 to 120
3	121 to 150
2	151 to 180
1	181 to 210
0	over 210

Drying Test—Weight Factor=0.6

Rating: Based on set to touch time

Rating	Minutes
10	0 to 30
9	31 to 60
8	61 to 90
7	91 to 120
6	121 to 150
5	151 to 180
4	181 to 210
3	211 to 240
2	241 to 270
1	271 to 300
0	over 300

If the film is not tack free in 24 hours, subtract one point for each day after the 24-hour reading until the film is tack free. If the film is tack free in 8 hours, add one point.

Hardness—Weight Factor=0.5

Equivalent to one-third of the number of swings of the Sward Rocker on the film after drying 192 hours, 30 or more swings being rated as 10.

TABLE IV

Limed Rosin Varnish Tests

	Cooking Time	Drying	Hardness	Kauri Red.	Cold Water Resist.	Hot Water Resist.	Alkali Resist.	Appearance	Weighted Figure
Factor	0.4	0.6	0.5	0.4	0.2	0.2	0.3	0.4	
G Bodied Linseed	4	2	10	6	2	0	5	7	14.1
Conjugated Linseed	6	7	6	7	2	0	1	10	17.1
Linseed Penta	9	6	10	6	4	0	10	7	21.2
Dehydrated Castor	6	4	5	7	2	0	2	10	15.1
Fatty Tall Oil	....	....	....	....	....	....	....	....	....
G Bodied Soybean	1	1	2	10	2	0	1	5	8.7
Conjugated Soybean	6	2	4	10	2	0	1	10	14.3
Soybean Penta	4	3	3	10	2	0	8	10	15.7
Soybean Mannitol	4	6	5	6	3	0	2	7	14.1
Soybean Sorbitol	3	6	4	8	1	0	2	7	13.6
Q Bodied Linseed	4	2	10	6	2	0	5	7	14.1
Linseed Polypenta	8	9	4	6	1	1	1	7	16.5
Linseed Mannitol	4	9	10	5	5	7	0	10	20.4
Linseed Sorbitol	5	6	7	3	3	0	4	7	14.9
Soybean Polypenta	7	1	3	7	1	1	1	10	12.4
Soybean Maleic Glyc	....	....	....	....	....	....	....	....	....
Soybean Maleic Penta	6	6	8	5	9	0	10*	10	20.8
Z2 Bodied Linseed	4	2	10	6	2	0	5	7	14.1
Linseed Maleic Glyc	....	....	....	....	....	....	....	....	....
Linseed Maleic Penta	7	9	10	5	2	0	4	10	20.8

TABLE V

Single Pigment Paint Tests

	Consistency	Drying	Water Permeability	Tensile Strength	Taber Abrasion	Hardness	Gloss	Appearance	Weighted Figure
Factor	0.3	0.4	0.4	0.4	0.4	0.4	0.4	0.3	
G Bodied Linseed	9	6	3	1	5	1	8	7	14.4
Conjugated Linseed	10	6	2	1	5	1	10	10	16.0
Linseed Penta	8	6	3	4	8	1	9	7	16.8
Dehydrated Castor	7	7	1	3	7	2	8	7	15.4
Fatty Tall Oil	9	0	3	2	6	1	8	10	13.7
G Bodied Soybean	9	0	3	0	0	1	9	10	10.9
Conjugated Soybean	9	0	2	0*	0	1	9	10	10.5
Soybean Penta	8	4	3	2	4	2	7	10	14.2
Soybean Mannitol	0*	2	2	0	4	1	7	5	7.9
Soybean Sorbitol	0*	4	2	1	5	1	8	7	10.5
Q Bodied Linseed	6	5	4	2	7	2	9	7	15.5
Linseed Polypenta	8	9	2	6	8	3	8	7	18.9
Linseed Mannitol	0	5	4	2	8	1	9	7	12.7
Linseed Sorbitol	0	6	3	3	8	2	9	7	14.5
Soybean Polypenta	7	8	1	5	7	3	8	7	17.0
Soybean Maleic Glyc	7	4	1	0	5	1	8	10	12.7
Soybean Maleic Penta	6	5	0	6	6	6	7	10	16.8
Z2 Bodied Linseed	9	8	5	4	7	2	5	10	18.1
Linseed Maleic Glyc	8	8	3	3	8	1	6	10	17.0
Linseed Maleic Penta	5	7	2	5	7	2	8	10	16.9

Kauri Reduction—Weight Factor=0.4

Rating	
10	Pass 130%
9	Pass 120%
8	Pass 110%
7	Pass 100%
6	Pass 90%
5	Pass 80%
4	Pass 70%
3	Pass 60%
2	Pass 50%
1	Pass 40%
0	Fail 40%

Cold Water Resistance—Weight Factor=0.2

Rating	
10	Unaffected
9	Pass
8	Fail 8 days
7	Fail 7 days
6	Fail 6 days
....	.....etc.....

Hot Water Resistance—Weight Factor=0.2

Rating	
10	Unaffected
9	Pass
8	Slight failure (dull)
7	Fail
6	Fail, no whitening in 50 minutes
5	Fail, no whitening in 40 minutes
4	Fail, no whitening in 30 minutes
3	Fail, no whitening in 20 minutes
2	Fail, no whitening in 15 minutes
1	Fail, no whitening in 10 minutes
0	Fail, whitens in 5 minutes or less

Alkali Resistance—Weight Factor=0.3

Rating: Bakelite BR 254 varnishes—one point for each 20 hours until failure.

Amberol 801 and Limed Rosin varnishes—one point for each 5 minutes until failure.

Appearance—Weight Factor=0.4

Rating: 0, 2, 5, 7, 10. Consider color, acid value,

TABLE VI

Mixed Pigment Paint Tests

	Consistency	Drying	Water Permeability	Tensile Strength	Taber Abrasion	Hardness	Gloss	Appearance	Weighted Figure
Factor	0.3	0.4	0.4	0.4	0.4	0.4	0.4	0.3	
G Bodied Linseed	9	5	6	4	5	3	4	7	15.6
Conjugated Linseed	9	4	6	5	5	2	5	10	16.5
Linseed Penta	8	6	6	7	8	4	3	10	19.0
Dehydrated Castor	7	8	6	8	7	4	4	10	19.9
Fatty Tall Oil	8	0	7	3	6	4	3	10	14.6
G Bodied Soybean	9	0	7	2	0	2	3	10	11.3
Conjugated Soybean	8	0	4	0*	0*	2	5	10	9.8
Soybean Penta	8	6	3	6	4	3	1	10	14.6
Soybean Mannitol	0*	2	6	2	4	2	2	5	8.7
Soybean Sorbitol	0*	2	7	4	5	2	2	7	10.9
Q Bodied Linseed	5	4	6	6	7	2	7	7	17.1
Linseed Polypenta	8	8	7	10	8	4	3	7	20.5
Linseed Mannitol	0*	6	7	6	8	3	3	7	15.3
Linseed Sorbitol	2	6	2	9	8	3	3	7	17.1
Soybean Polypenta	8	8	6	7	7	4	3	7	18.5
Soybean Maleic Glyc	4	5	6	5	5	3	5	7	14.9
Soybean Maleic Penta	5	5	3	8	6	5	3	10	16.5
Z2 Bodied Linseed	8	6	8	6	7	3	1	10	17.8
Linseed Maleic Glyc	5	8	7	8	8	3	2	10	18.9
Linseed Maleic Penta	6	9	7	4	7	4	1	10	17.6

viscosity change in one month, and condition after one month, and assign rating by inspection.

Paint Tests

Consistency—Weight Factor=0.3

Rating	Grams
10	140 to 170
9	171 to 200 or 130 to 139
8	201 to 230 or 120 to 129
7	231 to 260
6	261 to 290
5	291 to 320
4	321 to 350
3	351 to 380
2	381 to 410
1	411 to 440
0	over 440

Drying—Weight Factor=0.4

Rating	Hours
10	0 to 2
9	2 to 2¾
8	2¾ to 3½
7	3½ to 4¼
6	4¼ to 5
5	5 to 5¾
4	5¾ to 6½
3	6½ to 7¼
2	7¼ to 8
1	8 to 8¾
0	over 8¾

If the oil dries unusually fast or slow at 40°F. and 230°F. add or subtract one point from the above rating. If wrinkling occurs, subtract one point from the above rating.

Water Permeability—Weight Factor=0.4

Rating: 10 (1.20-specific permeability) and round off to nearest whole number. Maximum rating is 10.

Tensile Strength—Weight Factor=0.4

Rating: One point for each 5 Kg./sq. cm. of tensile strength.

Hardness—Weight Factor=0.4

Rating: One-half of the swings of the Sward Rocker plus one point for each 150 units of Shear hardness averaged. Maximum rating is 10.

Abrasion—Weight Factor=0.4

Rating	
10	0 to 125
9	126 to 175
8	176 to 225
7	226 to 275
6	276 to 325
5	326 to 375
4	376 to 425
3	426 to 475
2	476 to 525
1	526 to 575
0	over 575

Gloss—Weight Factor=0.4

Rating: Divide value for 60° reflectance by 10 and round off to nearest whole number.

Appearance—Weight Factor=0.3

Rating: 0, 3, 5, 7, 10. Consider appearance, brushing, leveling, color, daylight reflectance, drying odor, and after yellowing and assign rating by inspection.

When comparing all the evaluation tests made on a given oil with the tests used for grading purposes, all analytical constants, with the exception of color, appearance, and odor, are omitted from the grading system since these constants serve to characterize the oil and are not truly indicative of performance characteristics.

TABLE VII

Classified Oil Evaluation Average

	Oil	Varnish	Paint	Total Aver.
Linseed Polypenta	33.8	20.1	19.7	76.3
Linseed Penta	29.4	21.5	17.9	68.8
Linseed Maleic Penta	28.3	22.4	17.2	67.9
Linseed Maleic Glyc	24.3	24.5*	18.0	66.8
Soybean Polypenta	30.3	18.0	17.8	66.1
Soybean Maleic Penta	23.7	19.4	16.6	60.7
Dehydrated Castor	22.5	18.7	17.6	58.8
G. Bodied Linseed	23.1	18.7	15.0	56.8
Linseed Sorbitol	22.9	18.1	15.8	56.8
Conjugated Linseed	22.2	17.9	16.2	56.3
Q Bodied Linseed	21.5	17.6	16.3	55.4
Linseed Mannitol	19.7	21.4	14.0	55.1
Z2 Bodied Linseed	20.0	17.0	18.0	55.0
Soybean Maleic Glyc	19.4	20.0	13.8	53.2
Soybean Penta	20.9	17.6	14.4	52.9
Soybean Sorbitol	14.1	16.4	10.7	41.2
Soybean Mannitol	15.5	17.1	8.3	40.9
Conjugated Soybean	12.3	14.6	10.2	37.1
Fatty Tall Oil	11.3	.....	14.2	36.1*
G Bodied Soybean	9.0	13.1	11.1	33.2

Table VII shows the various oils arranged in order of merit as determined by the averages received under the rating scheme just described, the oil having the best performance characteristics being rated first. It must be remembered that the groupings of the test results were arrived at in an entirely empirical manner by simply examining the data obtained under each test so that if an oil achieves a total rating of 100.0 it is not necessarily a perfect oil, but merely a very good one. Also, it is not claimed that the averages yield a quantitative measurement of the quality of an oil, or the differences between the oils, but they do permit more or less qualitative comparisons to be made between a large number of oils rapidly and accurately.

It might also be pointed out that the weightings given to each test in arriving at the final average, while they are considered to be suitable for a general evaluation of the oils, could easily be changed to classify the oils for more specific end uses without requiring the whole rating system to be changed.

REFERENCES

1. Bolley, D. S., and Gallagher, E. C., J. Am. Oil Chem. Soc., *24*, 146 (1947).
2. Houston, G. W., Gallagher, E. C., and Bolley, D. S., previous paper.