These equations can be verified by substituting the experimental cooking data for Series A and Series B meats in Equations 7 and 8 and solving for the time T. A comparison between the actual cooking times and the times as calculated from these equations is Given in Table II. It will be observed that there is a reasonably close agreement between the actual and the calculated values. This indicates that the methods used to correlate the cooking variables for whole meats are valid, at least for practical purposes.

Summary

It has been demonstrated that the rate of disappearance of free gossypol during pressure cooking correlates well when using the equation of a second order chemical reaction. This equation applies to raw seed, whole meats, flaked meats, and solvent extracted flakes. For whole meats it was shown that the value of the rate constant K for the disappearance of free gossypol varies in direct proportion to the initial moisture content of the meats; and the log of K varies linearly with the temperature of the meats. Based on these factors a method has been presented by which the three cooking variables: moisture, temperature, and time, can be correlated into a single equation for any one series of cooks on cottonseed meats.

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Chemical Investigation of the New England Horse Chestnut, Aesculus hippocastanum[1]

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IN the early years of the last war the shortage of oils made the investigation of hitherto unimportant sources of oil worth exploring. The fruit of the horse chestnut, *Aesculus hippocastanum*, was reported as being used in Europe as a source of oil. The genus Aesculus, because of the striking appearance and the abundance of the various species, has interested many investigators, and papers recording the results of their work have appeared since 1833 (7). Romanesi (8) in 1834 mentioned obtaining the oil by heating and pressing the nuts. Stillesen (11) in 1909 was the first person to carry out anything approximating a thorough investigation. He reported the oil as having the following constants: d^{15}_{15}, 0.9260; n^{20}_{D}, 1.4747; saponification value, 194.5; iodine value, 95.4; Reichert-Meissl value, 1.54; Hehner value 92.9; acetyl value, 13.5. Other investigators reporting comparable values are Kaufmann and Baltes (6), Rousset (9), Sabalitschka (10), Heiduschka and Zeilers (3), and Chaplet (1). Kaufmann and Baltes (6) in 1938 reported the acid content to be linolenic, 2.2%; linoleic, 22.7%; oleic, 67.2%; stearic, 3.6%; palmitic, 4.4%. This work has been confirmed by Chopin (2) in 1946. In this hemisphere grows another member of the genus, the American buckeye. These facts led to the initiation of work in this laboratory on nuts from these two sources. A complete chemical analysis and an investigation of feasible commercial values are to be carried out.

The chemical constants do not reveal anything unusual. The iodine number assigns the oil to the non-drying class. Fatty acids of low molecular weight are not a part of its glyceride structure. Monethenoid unsaturation apparently predominates over the polytype. The oil analyzed in this laboratory was extracted from meal of the whole nut (kernel and shell) ground to pass through a 50-mesh screen and extracted with petroleum ether (b.p. 40°-72°) for 50 hours. The yield of oil was approximately 5%. The oil appeared reddish brown by transmitted light and a deep greenish yellow by reflected light. It had a pronounced bitter taste. The following physical constants were determined: specific gravity at 20° C. 0.9047; index of refraction at 25° C. 1.4633.

The chemical constants were determined by well-established procedures (5) and are shown in Table I.

TABLE I

Chemical Constants of Horse Chestnut Oil

Saponification number	167.5
Unsaponifiable matter (%)	2.97
Total fatty acids (%)	92.4
Soluble acids (% as butyric)	1.13
Saturated acids (%)	6.67
Unsaturated acids (%)	84.73
Iodine number	103.0
Thiocyanogen number	76.0
Hehner number	89.0
Acetyl value	17.2
Acid value	14.9
Reichert Meissl number	0.00
Polenske number	1.05

Separation of the Unsaturated Acids. The oil was saponified in an alcohol solution with potassium hydroxide, and the fatty acids were converted to the lead salts by treatment of the faintly acid solution with alcoholic lead acetate. The lead salts were separated according to a modified Twitchell lead-salt-alcohol separation as given by Hilditch (4). From

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TABLE II

Analytical Data for Annual Crops of Horse Chestnut

Constant	1941	1943	1944	1945	Misc.	1946	1947
Index of refraction	1.4662	1.4633	1.4601	1.4637	1.4690	1.4638	1.4639
Specific gravity	0.9076	0.9041	0.9041	0.8993	0.9077	0.9130	0.9011
Total fatty acids (%)	92.35	92.39	92.40	92.46	92.40	91.86	92.1
Acid number*	17.7	13.6	12.92	15.8	13.60	14.66	24.0
Saponification number	167.0	167.0	167.2	167.8	168.7	179.3	189.0
Saponification equivalent*	334.3	334.3	334.8	334.2	332.5	314.0	297.0
Unsaponifiable matter (%)	3.10	2.65	3.03	3.12	3.45	3.73	3.00
Acetyl value	16.7	16.2	17.7	18.3	17.3	17.4	12.81
Iodine number	101.0	103.0	98.43	104.0	109.0	104.7	102.9
Reichert-Meissl number	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Thiocyanogen number	76.0	76.2	74.0	76.5	76.6	78.85	76.5
Oil in nut (%)	5.90	5.94	6.18	5.70	6.00	6.00	6.10

* Consistent results were obtained only when pH meter was used for titrations.

175 g. of the oil there was obtained 130 g. (84%) unsaturated acids. The unsaturated fatty acids were converted to the methyl esters by warming methyl alcohol in the presence of 2% H_2SO_4. The mixture of esters thus obtained had a b.p. of 145°-175° at 1.5 mm. Fifteen cuts were obtained when the material was fractionally distilled. The fractionation column was an electrically heated packed column fitted with an arrangement for total reflux and adjustable distillate collection.

The ester fractions were dealt with according to Hilditch (4). The saponification equivalent and the iodine value of each fraction were determined. The percentage of saturated esters present in each fraction was determined by oxidation with potassium permanganate in acetone. Analysis showed that the unsaturated esters were comprised mostly of methyl oleate and methyl linoleate.

Detection of Linolenic Acid. The existence of linolenic acid in the oil was indicated by the formation of an ethyl ether insoluble precipitate of hexabromide on addition of bromine in the cold (—5°). This was only present in a trace amount.

Saturated Methyl Esters. The lead salts of the saturated acids were heated with hydrochloric acid and the acids were isolated in the usual manner. The crude saturated acids amounted to 6 to 7% of the weight of the original oil. To identify the acids the methyl esters were formed and the resulting esters fractionated at 1.5 mm. pressure. These fractions were treated in the same manner as the unsaturated esters.

The approximate percentage composition of the fatty acids of the oil from horse chestnuts was: stearic, 2.10%; palmitic, 4.8%; oleic, 65.3%; linoleic, 21.2%; and a trace of linolenic.

TABLE III

Percentage Composition of the Oil of Several Annual Crops

Acids	1941	1943	1944	1945	1946	1947
Stearic	1.9	2.1	2.0	2.1	2.0	1.1
Palmitic	4.3	4.7	5.4	5.0	4.3	4.3
Oleic	65.2	65.5	65.2	62.9	65.0	65.7
Linoleic	20.9	19.6	19.5	21.5	19.4	19.5
Linolenic	Trace	Trace	Trace	Trace	Trace	0.3

The oils from six annual crops of horse chestnuts were studied in order to determine if weather conditions had any significant effect on the chemical composition. Table II shows a comparison of the chemical and physical constants of these oils. Table III shows the summary of the fatty acid content of the six crops. The tables show that there is no significant difference in the chemical constants of these annual crops.

Summary

The analysis of the oil from the American species of *Aesculus hippocastanum* shows the oil to be similar to the European species. The constants reported by Stillesen (11) and Kaufmann and Baltes (6) are of the same order of magnitude as found in this investigation. The same is true of the fatty acid content except in the case of linolenic. European (6) investigators report 2.2% linolenic, and the American species contains only a trace.

The oil of the horse chestnut, *Aesculus hippocastanum*, is of the non-drying type. The approximate percentage composition of the fatty acids of this oil has been found to be stearic, 2.1; palmitic, 4.8; oleic, 65.3; linoleic, 20.2; and a trace of linolenic.

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