The Conidendrols as Inhibitors of Oxidation and Polymerization

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IT has previously been pointed out (7) that relatively pure conidendrin is readily available in large quantities from the sulfite waste liquors produced during the pulping of western hemlock. Fisher *et al.* (3) demethylated alpha conidendrin with hydrobromic acid, thereby obtaining a light tan glassy solid which they called norconidendrin. This material was found to have marked activity in preventing oxidative deterioration in fats and oils. Erdtman and Lindberg (1) demethylated alpha conidendrin with pyridine hydrochloride and obtained an isomeric demethylation product in good yield which they called beta norconidendrin. More recently, the demethylation of alpha and beta conidendrin has been investigated by Hearon *et al.* (5). The demethylation of either alpha or beta conidendrin with pyridine hydrochloride results in the formation of beta conidendrol, readily recoverable in pure crystalline form. Demethylation of alpha and beta conidendrin with hydroiodic acid, on the other hand, produces the corresponding alpha and beta conidendrols. It appears therefore that alpha conidendrin is isomerized to beta conidendrin in the presence of pyridine hydrochloride prior to its demethylation whereas demethylation proceeds without inversion with the acidic reagent. Both alpha and beta conidendrols have recently become available, and this has stimulated research on their use as stabilizers in a variety of products. These include the stabilization of wax paper coatings, lubricating oils, and oil well drilling muds (10, 11). They have also been found highly effective in retarding the deterioration of certain butadiene copolymers, in stabilization of vinyl type monomers, and in preventing the aging and discoloration of rubber articles. They have proved however to have no value as synergists in pyrethrin insecticides.

Moore and Bickford (6) compared the relative effectiveness of the two forms of the conidendrols with other well known antioxidants in stabilizing edible fats and oils against rancidification. The acceptability of the conidendrols as stabilizers for food products will depend on the results of toxicological studies which are still in progress.[2] After nine months of feeding tests no adverse effects have been noted on the health, growth, and activity of rats receiving a diet containing up to 1% of the conidendrols.

A number of the compounds currently used in stabilizing fats and certain monomers are derived from aromatics which are now in short supply. The possibility of supplementing or replacing these materials with the conidendrols has proven feasible. The results obtained in stabilizing fats and candies against rancidification as well as stabilizing butadiene copolymers and vinyl type monomers by use of the conidendrols are reported below.

Antioxidant for Fats

The antioxidant activity of alpha and beta conidendrols[3] were compared with two typical aromatic antioxidants, butylated hydroxyanisole and di-*tert*-butyl-*p*-cresol, in edible grade cottonseed and peanut oils, in cottonseed oil hydrogenated to shortening consistency, and in prime steam rendered lard. Each of these compounds was incorporated into each substrate in concentrations of 0.01, 0.05, and 0.10% with the aid of 1-3 ml. purified absolute ethanol. An equivalent amount of ethanol was added to the control sample. All of the fats were initially free of peroxides. The antioxidant efficiency was determined by the active oxygen method (4, 8). The antioxidant-treated fats and controls were aerated at 97.7°C. with purified air at a rate of 2.33 ml./sec. The rate of peroxide accumulation was determined by periodically withdrawing one-gram portions of fat from duplicate samples followed by determination of the peroxide content in the usual manner. Comparisons were made of the time required to accumulate a peroxide content of 100 me./kg. Inspection of the data in Table 1 indicates, with one exception, that at any concentration of antioxidant, the fats are more effectively stabilized by the conidendrols. Although the conidendrols are quite effective in the stabilization of the cottonseed oils, they are somewhat more so in the case of peanut oil. In every instance

TABLE I

Comparison of Antioxidant Activities of the Norconidendrins in Various Fats[a]

Antioxidant	Per cent	Cottonseed oil	Hydrogenated cottonseed oil[b]	Peanut oil	Lard
Control[c]	......	9.1	121	5.5	5.0
α-Conidendrol	0.01	10.1	153	11.7	33.1
α-Conidendrol	0.05	13.0	270	......	99.0
α-Conidendrol	0.10	20.9	412	38.0	136.0
β-Conidendrol	0.01	11.4	174	9.6	44.0
β-Conidendrol	0.05	17.5	347	......	110.0
β-Conidendrol	0.10	25.6	453	37.5	146.0
Butylated hydroxyanisole	0.01	6.6	108	......	31.0
Butylated hydroxyanisole	0.05	7.3	158	......	56.0
Butylated hydroxyanisole	0.10	7.3	172	......	68.0
Di-*tert*-butyl-*p*-cresol	0.01	9.4	118	......	26.5
Di-*tert*-butyl-*p*-cresol	0.05	14.6	172	......	50.0
Di-*tert*-butyl-*p*-cresol	0.10	18.0	184	......	79.0

[a] The relative antioxidant activity is expressed as the number of hours required by the sample to attain a peroxide content of 100 milliequivalents per kilogram of fat during aeration at 97.7°C. with an air flow of 2.33 ml./sec.

[b] Iodine value of hydrogenated oil was 61.4 by the Wijs method with a 30-minute reaction time.

[c] Substrate without added antioxidant.

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[2] Toxicity tests are being conducted at the Western Regional Research Laboratory, Albany, Calif., and the results obtained will be published when completed.

[3] The mention of these and other commercial products do not imply endorsement or recommendation by the Department of Agriculture over others having similar properties but are mentioned as a part of the exact experimental conditions used in the work being reported.

beta conidendrol was superior to the alpha form. The conidendrols were more effective in stabilizing lard against oxidation than vegetable oils, which is to be expected because the former contains no appreciable quantities of natural antioxidants. This is also evident in comparing the effects of individual and mixed antioxidants on the stability of a prime steam rendered lard.

PCP-#5 (2) (acetone-catechol condensation product), alpha and beta conidendrol, and their mixtures were compared at the various concentrations as shown in Table II. The antioxidant index or ratio of AOM hours of stabilized to unstabilized substrate, measured at 0.05% concentration for beta conidendrol, was found to be 11.6 and that for PCP-#5, 12.0. It is obvious therefore that each antioxidant affords approximately equal protection to the lard at that concentration. On the other hand, the antioxidant index for a mixture of these two (0.05% each) was only 13.8, which represents an insignificant increase over the values obtained for the individual antioxidants. Apparently it is difficult to improve the stability of a fat which contains nearly an optimum amount of antioxidant.

TABLE II

Antioxidant Activities of the Conidendrols, PCP No. 5, and Mixtures in Lard

Antioxidant	Concentration, %	AOM hours[a]	Antioxidant index[b]
Control	0	9.5	1.0
α-Conidendrol	0.05	99.0	10.4
PCP No. 5	0.05	114.0	12.0
α-Conidendrol	0.05	......	......
Plus PCP No. 5	0.05	136.0	14.3
α-Conidendrol	0.10	136.0	14.3
β-Conidendrol	0.05	110.0	11.6
β-Conidendrol	0.05	......	......
Plus PCP No. 5	0.05	131.0	13.8
β-Conidendrol	0.10	146.0	15.4

[a] Number of hours required by the sample to acquire a peroxide content of 100 milliequivalents per kilogram of fat during aeration at 97.7°C. with an air flow of 2.33 ml./sec.

[b] Ratio of AOM hours of stabilized to unstabilized substrate.

Antioxidant for Candies

The effectiveness of both alpha and beta conidendrol in protecting fat-containing candies against rancidification was compared with that of butylated hydroxyanisole and di-*tert*-butyl-*p*-cresol. A butter cream fondant containing 5% fat was employed in a series of four tests in which a) the antioxidant was incorporated into the candy at a concentration of 0.10% based on the fat content; b) 10 parts per million of copper stearate was added, based on the weight of the butter; c) both copper stearate and antioxidant were employed; and d) a control without inhibitor or accelerator. The candies were stored in an air oven at 86°F., and samples were removed at intervals for examination. The fat was extracted and its peroxide content determined in the usual manner.

At the end of 21 weeks the peroxide content of the control was 15 me./kg. of fat, that of the sample containing only copper stearate was 24, while those samples which contained antioxidants with and without copper stearate had a peroxide value of zero. All of the antioxidants were equally effective in preventing rancidification of the fat in the candy but had no significant effect in retarding the development of free fatty acids.

Stabilizer for Vinyl Type Monomers

Alpha and beta conidendrol were compared with hydroquinone as stabilizers of monomeric methyl methacrylate, vinyl acetate, and styrene which had been purified by alkali washing, drying, and distillation. Duplicate samples were placed in Gardner-Holt viscosity tubes and tightly stoppered. The samples of styrene were maintained at 65°C. in the dark until the viscosity (measured at room temperature) attained a value of 100 poises. The vinyl acetate and methyl methacrylate samples were irradiated with ultraviolet light at room temperature in a manner that insured that each sample received an equivalent amount of irradiation. As before, the time required by the samples to attain a viscosity of 100 poises was taken as a measure of inhibitor efficiency.

It is evident from the data presented in Table III that the conidendrols possess marked antipolymerization properties for vinyl type monomers. Although they are not as effective as hydroquinone, which is one of the best inhibitors, they are non-volatile, and their use renders it possible to distill the monomer rather than to alkali-wash to remove the stabilizer. Alpha conidendrol is more effective than the beta isomer in preventing polymerization whereas the beta form is more effective in stabilizing fats and oils against oxidative rancidification.

TABLE III

Comparison of Antipolymerization Activities of the Norconidendrins in Various Monomers

Inhibitor	Per cent	Styrene[a,c]	Methyl methacrylate[b,c]	Vinyl acetate[b,c]
Control[d]	......	58	3	12
α-Conidendrol	0.01	104	14	13
α-Conidendrol	0.10	162	17	103
β-Conidendrol	0.01	86	25	13.5
β-Conidendrol	0.10	92	26	33
Hydroquinone	0.01	121	27	15
Hydroquinone	0.10	213	72	72

[a] Expressed as the time in hours required at 65°C. to attain a viscosity of 100 poises measured at room temperature.

[b] Expressed as the number of hours required under ultraviolet irradiation for the samples to attain a viscosity of 100 poises at room temperature.

[c] All viscosities were measured by means of a Gardner-Holt Bubble Viscometer.

[d] Substrate without added inhibitor.

Stabilizer for GR-S Polymer[4]

Beta conidendrol was compared as an antioxidant at four concentrations for preventing viscosity changes, resinification, and discoloration in GR-S polymer with phenyl beta naphthylamine (PBNA), which is known to afford good protection to this type polymer, as well as Wingstay-S and ELGI. GR-S latex was prepared at 122°F. to 73.1% conversion and 54 ML-4 viscosity. Each compound was added to the latex in the form of a slurry which was prepared as follows: The antioxidant was dissolved in 50 ml. of acetone containing 0.4 gram of Daxad-11 and the resulting solution mixed well with one quart (0.946 l.) of water. The suspension was added to the latex followed by the coagulation of the mixture with salt and acid. The raw polymers containing, respectively, 0.375, 0.813, 1.25, and 1.50 parts of antioxidant per 100 parts of rubber were heated in air at a temperature of 100°C. for 2, 4, 8, 24, and 48 hours. Samples were removed at

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[4] The data reported in this section was taken from a technical report, University of Akron Government Laboratories.

each interval and examined for viscosity changes, the appearance of oxidized surface coatings, and for the formation of graininess on remilling. Data with respect to the change in viscosity are given in Table IV.

TABLE IV

Comparison of Beta Norconidendrin With Various Inhibitors in GR-S Polymer Heat-Treated at 100°C.

Inhibitor	Concentration, p.h.r.[a]	Viscosity[b]					
		Hours					
		0	2	4	8	24	48
β-Conidendrol	0.375	54	46	36	29	50	60
β-Conidendrol	0.813	55	56	56	57	55	52
β-Conidendrol	1.25	58	57	57	56	54	50
β-Conidendrol	1.50	57	58	57	58	57	56
ELGI	0.375	58	55	55	50	35	54
ELGI	0.813	59	58	60	59	59	64
ELGI	1.25	57	55	58	58	60	64
ELGI	1.50	55	56	57	57	60	61
Wingstay-S	0.375	55	40	31	26	48	69
Wingstay-S	0.813	53	39	29	23	49	67
Wingstay-S	1.25	55	42	33	24	47	69
Wingstay-S	1.50	56	48	....	33	49	64
PBNA	0.375	57	57	57	54	48	33
PBNA	0.813	55	54	54	47	28	26
PBNA	1.25	53	52	51	49	36	25
PBNA	1.50	54	52	50	46	30	23

[a] Parts of inhibitor per 100 parts of rubber.
[b] Expressed as ML-4 units.

Both beta conidendrol and ELGI when employed in concentrations of 0.813 p.h.r. or higher are very effective in preventing viscosity changes in the polymer. The lowest concentrations of these antioxidants, and any concentration of PBNA and Wingstay-S employed, were ineffectual in this respect. From Table IV it is apparent that 1.25 p.h.r. of beta conidendrol is the maximum concentration that need be employed, and probably the lower concentration of 0.813 would be adequate. The optimum concentration was not established. From Table IV it is evident that beta conidendrol is the most effective antioxidant for the protection of the polymer. Whereas a small amount of stiffening occurred in the polymer containing ELGI after 48 hours' treatment, this is not the case of beta conidendrol in which only a small decrease of viscosity was found in the polymer. Samples of the polymer which contained 1.25 p.h.r. of beta conidendrol, ELGI, and PBNA showed no resinification or surface coating after heating for 48 hours. All remilled samples of the stabilized polymer were uniform and homogeneous. On the other hand, Wingstay-S produced a surface coating and heterogeneity on remilling.

The procedure prescribed by the Synthetic Rubber Division, R.F.C., (9) was followed in the discoloration, staining, and pigmentation tests. Except for the samples containing PBNA, none of the other compounded vulcanizates showed any discoloration. It is known however that PBNA causes discoloration and staining. PBNA produced a deep brown stain on an exposed lacquered surface of the raw polymer while Wingstay-S and ELGI produced a slight but definite staining. Only a negligible amount of staining was observed in the polymer containing beta conidendrol. Of the four antioxidants evaluated in the stabilization of GR-S polymers beta conidendrol appears to be superior in every respect.

Summary and Conclusions

Alpha and beta conidendrol have been tested and intercompared with accepted stabilizers in the following applications: a) as antioxidants for the prevention of rancidification in fats, oils, and fat-containing candies; b) as stabilizers against aging and resinification in GR-S type polymers; and c) as additives for inhibiting the polymerization of vinyl type monomers. Accepted acceleration tests were employed in determining the relative efficiencies of the various stabilizers. Such tests do not necessarily yield quantitative information concerning stabilization performance under conditions of use. However experience has shown that any marked differences observed in these tests indicate proportional differences in normal use. On the basis of the data reported here it may be concluded that the conidendrols are approximately equal or superior to other stabilizers in current use in their respective fields. In addition, the conidendrols are produced from a raw material which is in abundant supply and offer the possibility of supplementing or replacing stabilizers derived from benzene or naphthalene.

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