

Effect of Synergists on Activity of Gallates

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Abstract □ Tartaric, citric, ascorbic, and orthophosphoric acids were used to study the effect of synergists on the pro-oxidation and antioxidation produced by methyl, ethyl, propyl, octyl, decyl, and dodecyl gallates on the oxidation of aldehydes dispersed in cetomacrogol solutions at 25° in the presence of cupric sulfate. Although antioxidation was found to be enhanced by all the acids used in this study, pro-oxidation was enhanced only by tartaric acid. Citric, ascorbic, and phosphoric acids appear to be only synergistic with the gallates.

Keyphrases □ Gallates, activity—synergists effect □ Antioxidation effect—gallates-synergists □ Pro-oxidation effect—gallates-synergists

Synergism may be said to have occurred if the overall effect of the two components in combination is greater than is expected on the basis of a summation of the effects of each component alone. Olcott and Mattill (1, 2) used ascorbic acid as a synergist in their studies of phenolic and amine antioxidants on the oxidation of unsaturated esters and fatty acids. This acid has also been reported as being an antioxidant (3), a pro-oxidant (4), and being without effect on autoxidation (5). Citric acid had been found to form chelates with iron and copper ions (6–8) but did not appear to be an antioxidant on its own. Tartaric acid had been used as a synergist for phenolic antioxidants and seemed to act by chelating metal ions (9–11). Phosphoric acid had been shown to be an effective synergist for gallates (12). In view of the pro-oxidation and antioxidation produced by gallates (13) it is appropriate to study the action of common synergists in such systems.

EXPERIMENTAL

Materials—The aldehydes, gallates, cetomacrogol, and cupric sulfate were the same as those described in a previous paper (13). The synergists were tartaric acid, m.p. 167–168.5°, citric acid,¹ m.p. 150–151°, ascorbic acid, m.p. 192–193°, and orthophosphoric acid.²

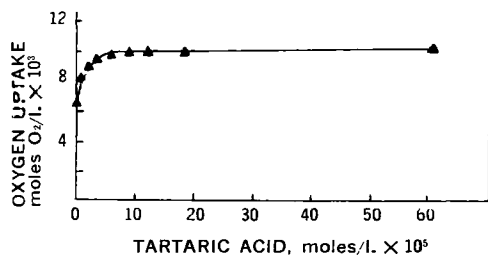


Figure 1—The effect of tartaric acid on the oxidation of benzaldehyde (0.1729 M) solubilized in cetomacrogol solutions (0.04 M) at 25° in the absence of cupric sulfate.

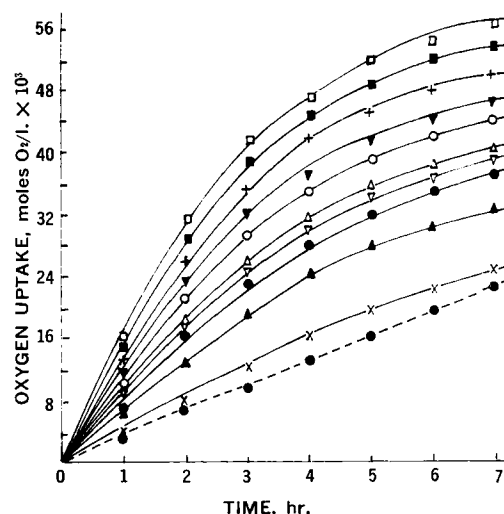


Figure 2—The effect of cupric sulfate (1×10^{-3} M) and varying concentrations of tartaric acid on the oxidation of benzaldehyde (0.1729 M) solubilized in cetomacrogol solutions (0.04 M) at 25°. Tartaric acid concentration $\times 10^{-4}$ M: \times , 0.6; \blacktriangle , 1.8; \bullet , 2.4; ∇ , 3.0; \triangle , 3.6; \circ , 4.8; \blacktriangledown , 6.0; $+$, 7.2; \blacksquare , 10.8; \square , 18.0 to 60.0; ---, control, without tartaric acid.

Apparatus—Warburg apparatus.³

Measurement of Oxygen Uptake—This was determined in the manner described previously (14) using the same system (13). For ease of comparison, equivalent molar concentrations of synergist and antioxidant were added.

RESULTS AND DISCUSSION

No oxygen uptake was found in the following systems: (a) tartaric acid in water; (b) tartaric acid in water containing cupric sulfate;

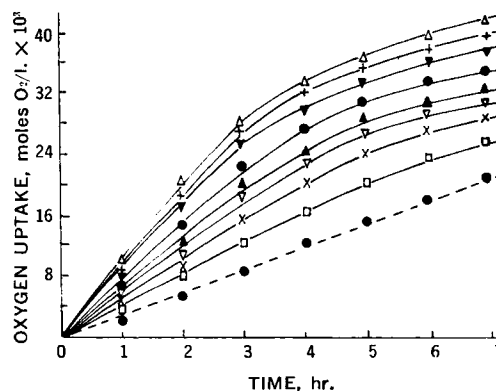


Figure 3—The effect of cupric sulfate (1×10^{-4} M) and varying concentrations of tartaric acid on the oxidation of benzaldehyde (0.1729 M) solubilized in cetomacrogol solutions (0.04 M) at 25°. Tartaric acid concentration $\times 10^{-4}$ M: \square , 0.3; \times , 0.6; ∇ , 1.2; \blacktriangle , 1.8; \bullet , 2.4; \blacktriangledown , 6.0; $+$, 9.0; \triangle , 10.8 to 21.0; ---, control, without tartaric acid.

¹ A. R., British Drug House, Ltd.

² A. R., Hopkin and Williams, Ltd.

³ Braun model VL-85.

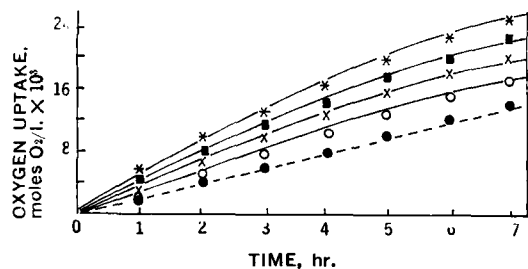


Figure 4—The effect of cupric sulfate (1×10^{-5} M) and varying concentrations of tartaric acid on the oxidation of benzaldehyde (0.1729 M) solubilized in cetomacrogol solutions (0.04 M) at 25° . Key: Tartaric acid concentration $\times 10^{-4}$ M: \circ , 0.15; \times , 0.6; \blacksquare , 2.1; $*$, 7.2; —, control, without tartaric acid.

(c) tartaric acid in cetomacrogol solution containing cupric sulfate; and (d) tartaric acid in cetomacrogol solution containing cupric sulfate and ethyl gallate, where the tartaric acid concentration was from 0.15 to 9.0×10^{-4} M, the cupric sulfate concentration was 1×10^{-4} M, the cetomacrogol concentration was 0.04 M, and the ethyl gallate concentration was from 0.15 to 9.0×10^{-4} M. In the absence of gallate and cupric sulfate, tartaric acid in cetomacrogol solutions containing benzaldehyde produced initially a slight pro-oxidation which increased gradually with increasing amounts of the acid, tending to become constant (Fig. 1). However, in the presence of cupric sulfate, but excluding gallate, the pro-oxidation was greatly enhanced and was dependent on the concentration of cupric sulfate used (Figs. 2-4). The magnitude of the observed pro-oxidation by tartaric acid with different cupric sulfate concentrations was much greater than the summation of the pro-oxidant effects due to the tartaric acid and cupric sulfate at their corresponding concentrations. The difference between the effects due to the different concentrations of tartaric acid was greater when a high cupric sulfate concentration was present. These observations suggested that tartaric acid probably interacted with cupric sulfate resulting in the pro-oxidation.

In the presence of gallate but absence of cupric sulfate, tartaric acid was synergistic to the antioxidant inasmuch as the oxygen uptake was less than that observed when only the antioxidant and benzaldehyde were present. When both gallate and cupric sulfate were included, tartaric acid enhanced the pro-oxidation and the antioxidant (Fig. 5). Similar results were obtained with the other gallates and also in surfactant solutions containing *p*-methylbenzaldehyde, cupric sulfate, tartaric acid, and the same series of gallates. It is probable that the enhanced pro-oxidation is due to the pro-oxidant effect of the acid (Figs. 2-4) and the enhanced antioxidant to a synergism between the acid and the gallate. Preliminary investigations have indicated that tartaric acid is not likely to be a synergist to the proposed cupric-gallate complex stated in a previous paper (13) and current studies seem to suggest the formation of cupric tartrate.

When citric acid in concentrations of 0.3 to 1.8×10^{-4} M was added to surfactant solutions containing benzaldehyde and cupric sulfate, neither pro-oxidation nor antioxidant was observed. This was also true for the same system when cupric sulfate was excluded. However, when citric acid together with a gallate were present, a marked synergistic effect was produced (Fig. 5). In addition, when added to those gallate concentrations which produced pro-oxidation when present alone, citric acid reduced the oxygen uptake to rates that were lower than that of the control.

Since citric acid was found to be inactive in the absence of gallate, it could be said to have no effect on the oxidation of benzaldehyde. In the presence of gallates, the reduction in oxygen uptake, irrespective of whether there was pro-oxidation or antioxidant showed

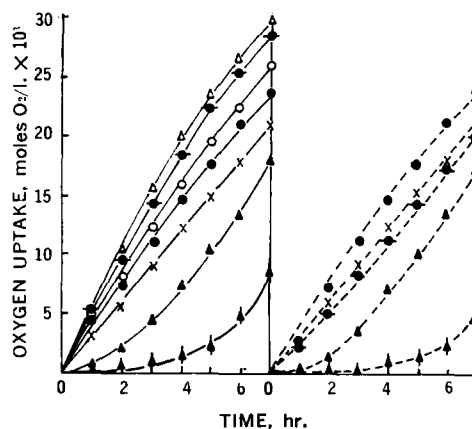


Figure 5—The effect of tartaric acid + ethyl gallate, and citric acid + ethyl gallate on the oxidation of benzaldehyde (0.1729 M) solubilized in cetomacrogol solutions (0.04 M) at 25° in the presence of cupric sulfate (1×10^{-4} M). Key: \circ , 0.3×10^{-4} M TA; \bullet , 0.3×10^{-4} M EtG; \ominus , 0.3×10^{-4} M TA or CA + 0.3×10^{-4} M EtG; Δ , 0.9×10^{-4} M TA; \blacktriangle , 0.9×10^{-4} M EtG; \blacktriangledown , 0.9×10^{-4} M TA or CA + 0.9×10^{-4} M EtG; \times , control, without acid or gallate. TA, tartaric acid; CA, citric acid; —, tartaric acid; ---, citric acid.

that citric acid was synergistic with the gallate. The mode of action of citric acid was not likely to involve chelation of the pro-oxidant ions since it did not promote oxidation of benzaldehyde in the presence of cupric sulfate. Similar behavior was found for the other gallates and for ascorbic and phosphoric acids under the same conditions.

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