ON PYROLYSIS, AND THE POSSIBLE CONTRIBUTION OF MALEIC HYDRAZIDE TOWARDS BENZO (a) PYRENE IN TOBACCO SMOKE[1]

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Recent findings of Patterson **et al.** (14) that maleic hydrazide (MH), when pyrolyzed in a nitrogen atmosphere yields benzo (a) pyrene (BaP), could lead to the implication that MH residues in tobacco could also yield BaP in tobacco smoke. Neat MH when pyrolyzed would give high enough concentrations of C_2 and C_4 units for them to polymerize to give BaP, but in MH-treated tobacco smokes the concentration of these C_2 and C_4 units are so low that the formation of BaP from the polymerization of these units is mathematically impossible. The only possible route for the formation of BaP from MH in MH-treated tobacco smoke is by the incorporation of MH C_2 and C_4 units in the tobacco smoke "carbon pool." But the possibility is exceedingly small. Evidence and data so far available on maleic hydrazide are not sufficient to suggest that MH in tobacco is a health hazard to the smoker.

Systematic study on the pyrolysis of pesticides in tobacco smoke is a powerful tool not only in the understanding of the fate of pesticides and other compounds present in minute quantities in tobacco, but also reveals events taking place during the smoking of tobacco.

Maleic hydrazide (MH) is one of the most important chemicals used in tobacco sucker control. Lately, its use has come under fire because of its suspected carcinogenecity (11). Further, recent studies of Patterson *et al.* (14) have shown that MH, when pyrolyzed in an inert atmosphere (nitrogen), yields benzo (a) pyrene (BaP). Even though Patterson and his associates have not shown that MH in tobacco upon smoking may be converted into BaP, it could be implied that such transformation does take place.

We have carried out systematic studies on the pyrolysis, in a nitrogen atmosphere, of pesticides such as p,p'-DDT (2,7,8), and endosulfan (5). From these studies we have found that pyrolysis of a compound in an inert atosphre involves three events: (1) the excitation of the molecule, (2) rearrangement of the excited molecule, or the breakdown of the excited molecule into fragments with the weakest bonds breaking preferentially, and (3) the rearrangement of the fragments produced (aromatization of the molecule is an example of it), or the recombination of the fragments to produce various products including dimers and polymers. Further, we also found that in a highly reactive atmosphere, such as present in tobacco pyrolysis zone, the pesticide molecule follows the same events as it does in an inert atmosphere excepting that the fragments of the pesticide molecule so produced do not react with each other. In all of our work on the breakdown of p,p'-DDT in tobacco smokes (2,6,9,10) and on the breakdown of endosulfan I (4), we have not found a single product which was formed contrary to our findings. Our studies on the breakdown of endosulfan I in tobacco smoke are not complete, but to date we have found endosulfan I and II, and endosulfan sulfate, with endosulfan ether being possibily present, in endosulfan I-treated tobacco smokes. In these studies we did not find, with the exception of methyl chloride, any other chlorohydrocarbon in the tobacco smokes.

The formation of BaP on the pyrolysis of MH in a nitrogen atmosphere has been attributed to the polymerization of C_2 units (14). This would be consistent with our findings. But the formation of BaP from MH-treated tobacco is a different matter.

In tobacco smokes there would be two possible routes for the

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formation of BaP from MH: (1) the polymerization of C_2 and C_4 units formed during the pyrolysis of MH as mentioned above, and (2) the incorporation of these C_2 and C_4 units by other fragments in the "carbon pool" of the tobacco smoke. As an example, consider the potential contribution of MH towards BaP formation in smoke of tobacco containing 200 ppm of MH (mole concentration, $200/112 \times 10^{-6} = 1.8 \times 10^{-6}$). According to the law of mass action the probability of the formation of BaP ($C_{20}H_{12}$) via the first route, with a theoretically maximum concentration of 3.6×10^{-6} and 1.8×10^{-6} for C_2 and C_4 units would be of the order of $(3.6 \times 10^{-6})^{10}$ and $(1.8 \times 10^{-6})^5$, respectively (cf. Avogadro's #, 6.02×10^{23}). This amounts to nil for all practical, and even, theoretical purposes. The probability of the formation of BaP via the second route would also be exceedingly insignificant for the following reasons: (1) with a maximum possible concentration of 3.6×10^{-6} and 1.8×10^{-6} moles, respectively, for C_2 and C_4 units, the maximum theoretical probability of these units resulting as BaP in tobacco smoke would be of the order of 3.6×10^{-6} and 1.8×10^{-6}, respectively; (2) Smith *et al.* (17) have shown that MH in tobacco on smoking yields several other products, such as, CO, acetylene, methane, HCN, succinimide, *etc.* and that a substantial portion of the MH is not converted into polyaromatic hydrocarbons (PAH); (3) our studies on the formation of PAH from the pyrolysis of stigmasterol (1) showed that BaP formed is only a small fraction (less than 4%) of the total PAH formed; and (4) according to Schlotzhauer *et al.* (15) "the hexane extract of the flue-cured tobacco contributes disproportionately to the total benzo (a) pyrene content of tobacco pyrolysate." This would indicate that the formation of BaP involves more of an aromatization reaction, e.g., from tobacco hydrocarbons and steriods, and less of a polymerization reaction, e.g., amino acids and sugars, *etc.*

The formation of BaP from a component of, or a compound present in tobacco, on smoking, not only depends upon the nature of the substance (e.g., DDT, hexachlorobenzene and other perhalogen organic compounds would not give BaP on pyrolysis), but also on the concentration in which they are present in tobacco (e.g, menthol is almost quantitatively distilled off intact during smoking (13), and this leaves very little possibility of its conversion into BaP).

Our studies (3) suggest that ideally the most desirable pesticide on tobacco would be a compound which leaves no residue at all in tobacco. However, if that is not possible then the decreasing order of desirability would be: (1) a non-volatile pesticide which decomposes into harmless degradation products during smoking, (2) a non-volatile pesticide which on smoking gives degradation products which though harmful *per se* do not significantly contribute to the hazard to the smoker; and (3) volatile pesticides, such as, DDT or TDE which could almost be quantitatively transferred into tobacco smoke.

So far studies on MH have shown that it is still the most effective sucker control agent (16). Its transfer rate into tobacco smoke, presumably due to its being carried over in the particulate matter, is small (12). The recent study of Smith *et al.* (17) reported above on the degradation of MH in tobacco smoke is not yet complete. Further, they have used a concentration of 5% MH in tobacco in their investigations. This concentration greatly exceeds the actual conentrations in the commercial MH-treated tobacco. This could not only change the character of the combustion of tobacco, but would also be expected to give different degradation products than that MH, which is present in the commercial MH-treated tobacco, would give on smoking.

Thus far it is reasonable to assume that there is not enough data or justification to consider the use of MH as a health hazard to the smoker.

Systematic studies on the pyrolysis of pesticides in tobacco smoke is a new and a powerful tool in the understanding of the fate of pesticides and other compounds present in minute quantities in tobacco during the process of smoking. It also reveals the events taking place during, and as a result of, smoking of tobacco. An example is the formation of methyl chloride and the very extensive methylation that takes place during the smoking of tobacco (9). Although methylation is known to be a potential cause of carcinogenesis, it is surprizing that investigations into the contribution of this methylation to the carcinogenesis has, so far, been almost completely neglected.

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