MUTAGENS IN HEATED FOODS

Michael W Pariza

(McCann et al., 1975). It should also be stressed that the temperature required to produce Trp-P-1, Trp-P-2, and related mutagens in food is in excess of 200°C and, hence, as with the carcinogenic hydrocarbons, the formation of these substances from amino acids and proteins is dependent upon relatively high temperature.

More recently, mutagenic activity has been found in a wide variety of foods processed under more modern heating conditions (Pariza et al., 1979a; b; Commoner et al., 1978; Spriggs et al., 1979, 1980). As shown in Fig. 2, bacterial mutagens detectable with the Ames test are present in commercially processed meats, cereals, and dairy products. The implication of these data is that virtually all heat-processed foods probably contain mutagenic activity. However, it has not been shown that these mutagens cause cancer in animals.

EFFECTS OF TIME AND TEMPERATURE ON MUTAGEN FORMATION

In order to obtain information on the effects of time and temperature on mutagen formation, Trp-P-1, ground beef during pan frying, my colleagues and I (Pariza et al., 1979b) conducted experiments using a specially designed grill having temperature variation at any point or between points of less than ±2°C (in contrast, most heating devices available commercially for use in the home vary by 10°C or more—The National Council on the Chemical Safety of Food. Prof. D.B. Lund, U.W. Food Science Department). Using uniformly prepared ground beef patties (115 g, 1 cm thick, 15% fat) we found that mutagenic activity readily developed at frying temperatures of 210°C or 260°C. In contrast, patties fried at 140°C...

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INHIBITION OF MUTAGENESIS AND CARCINOGENESIS

Considerable research effort has been directed at inhibiting mutagenesis and carcinogenesis, and many of these studies are pertinent to foods. For example, addition of nitrite to meat as a preservative is...
often associated with potential nitrosamine formation. However, at acid pH nitrite detoxifies mutagens produced by prolylating protein (Yoshida and Matsuoka, 1979). Additionally, a factor has been purified from extracts of sage. Sage leaves which inhibit bacte-
rial mutagenesis by a number of mutagens, including Trp-P-1 (interestingly, this factor also enhances the mutagenic activi-
ty of 1,2-diamino-4-nitrobenzene) (Ishoo et al., 1981). In addition, we have provided evidence for a mutagenesis inhibitor in fried and uncooked ground beef which appears to inhibit certain enzymes which activate mutagenic activity in fried ground beef and beef extract (Pariza et al., 1975a).

Wattenberg and colleagues (1976) have provided an extensive review of compounds which inhibit cancer induction when fed to ani-

mals before or with carcinogens. A partial list is shown in Table 1, and includes natural plant constituents

| Table 1 - CHEMICALS WHICH INHIBIT CANCER when fed before or with a carci-


ongen (Wattenberg et al., 1976) |
<table>
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<tr>
<td>2-naphthoflavone</td>
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<td>butylated hydroxytoluene (BHT)</td>
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<td>chlordecone</td>
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| (6-naphthoflavone), phenolic anti-


oxidants (BHT and BHA), drug (phenobarbital), insecti-

cides (chlordecone), contaminants (PCBs), and even weak carci-


ogens (certain polycyclic aromatic hydrocarbons). Inhibition of can-


cer effected by these chemicals appears due to the induction of enzymes which detoxify carci-


nogens. Under other conditions of assay, however, many of these same chemicals can enhance (pro-


mote) tumor formation (Peraia et al., 1977). Whether human cancer incidence is affected by such chemicals (Table 1) is unknown, but the possibility of cancer inhibi-


tion in humans by natural plant constituents and phenolic antiox-


idants is both intriguing and exist-


ing. Such factors may have bearing on the possible health significance of mutagens generated in food dur-


ing cooking. They may also con-


Selected foods were subjected to organic extraction and the results of testing the basic extracts (products 1-6, 8-10) of the acidic extract (product 7) for mutagenicity in the Ames test were plotted against the amount assayed. The symbols represent the means of duplicate assays with background revertant colonies subtracted (solvent controls 5-9 were 27 colonies per plate or less). Products: (1) sauced chicken broth; (2) canned beef broth; (3) crackers; (4) corn flakes; (5) rice cereal; (6) bread crust (soil); (7) Worcestershire sauce; (8) bread crumbs; (9) toast (surface); (10) coconut cookies. The symbols correspond to arbitrary designations as: moderately high (1-4 revertant colonies/g); low (0.1-0.3 revertant colony/g); low-marginal (aboub 0.5 revertant colonies/g); 0: levels of mutagic activity. From Pariza et al., 1976b.

Fig. 2 — MUTAGENIC ACTIVITY IN HEAT-PROCESSED FOODS

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tribute to the beneficial aspects of eating a well-balanced diet, in moderation.

SAFETY CONSIDERATIONS

The most important safety issue confronting this active area of research is the possible human health significance of mutagens in cooked food. It is clear that such compounds are not new to the human food supply but rather have been present since early man first learned how to control fire. Aside from considerations, touched upon above, that food is an extremely complex medium containing many chemicals with various pharmacological effects (some of which are anti-carcinogenic), what can we say about the relative hazard associated with mutagens generated in food during cooking?

In general, epidemiological studies indicate a correlation between increased cancer incidence at some sites and diets high in charred and/or heavily smoked foods (Park, 1952). There are not at present sufficient data to fully evaluate the possible role of basic mutagens (Figs. 1,4,4) in this suggested correlation, but it seems unlikely that health risk is great. There are several lines of experimental evidence for this conclusion. First, pre-carcinogenic studies on chemical, i.e., amino acid and protein pyrolysis mutagens are positive for some but not all tested compounds, but where positive carcinogetic activity is weak (Ishikawa et al., 1979; Takayama et al., 1979). Second, preliminary experiments on fried ground beef extracts containing bacterial mutagenic activity did not increase sister chromatid exchanges in bone marrow cells of mice, nor was there restoration of primordial oocytes in treated juvenile female mice (Pelton et al., 1989). Finally, we have found (unpublished) that mutagenic Ames test extracts of fried ground beef and commercial beef extract did not initiate skin cancer in mice, using the induction-promotion system of Boutwell (1974). Sugimura (1978) has emphasized the necessity of maintaining a rational perspective, based firmly on scientific evidence, in evaluating the potential risks associated with long-term ingestion of mutagens and carcinogens in low levels in food.

References on next page

Fig. 3 — MUTAGENIC ACTIVITY IN PAN-FRIED GROUND BEEF PATTIES

Fig. 4 — STRUCTURES OF 10 (2-amino-3-methylimidazole 8,5-bisoxo), Methyl (2-amino-3,5-dimethylimidazole 8,5-bisoxo), and MeIQ, (2-amino-3, 8-dimethylimidazole 4, 8-bisoxo)

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REFERENCES

Beisel, J. K. 1974. The function and mecha-
nism of promotion of carcinogenic CRC Crit.
Rev. Tox. 3: 77.
Campbell, T. C., and Hayes, J. R. 1974. The role
of aflatoxin metabolism in its toxic lesion.
Cornelison, B., Villahermosa, A. J., Dober, P.,
Formation of mutagens in beef and beef extract
Vinyl carbamate as a promutagen and a more
carcinogenic analog of ethyl carbamate. Cancer
Res. 34: 2788.
Elton, J. C., Carver, T., Cheung, J., Thappan,
L., Streamer, D., Tuzovicz, H., Hatch, B., Pif-
desso, L., and Morris, M. 1986. Evaluation of
mutagens from cooked hamburger with several
Griffith, W. A., Dietrich, R. A., and Parissi,
M. W. 1982. A new chromatographic method
for separating mutagens from commercial beef
extract and fried ground beef. In H. F. Schild (ed.)
Carcinogens and Mutagens in the Environ-
115-122.
Inouye, T., Mithieux, R., and Kada, T. 1981. Purifi-
cation and properties of a plant deoxynuclease
factor for the mutagenic principle of trypto-
phan pyrolysis products. J. Biol. Chem. 256:
342-353.
Ishibashi, T., Takahara, T., Kikugawa, T., Kawa-
ochi, T., Kihima, M., Matsumoto, N., Ushida,
on tryptophan pyrolysis products. In Naturally
 Occurring Carcinogens-Mutagens and Modi-
lators of Carcinogenesis, ed. E. C. Miller et al.
University Park Press, Baltimore, pp. 115-122.
Kasai, H., Yamazaki, Z., Wakahashi, K., Nagai,
M., Sumita, T., Yokomoto, S., Miya-
ue, T., Nijimura, Y., and Nakamura, S. 1980.
Potential new mutagens produced by heating fish
under certain conditions. Jap. J. Med. 20:
97-103.
Kim, S., Yamazaki, Z., Ushida, T., Yokomoto,
S., Miyawaki, T., Wakahashi, K., Nagai, M.,
Sumita, T., and Nakamura, S. 1981. Struc-
ture of a potent mutagen isolated from fried
Ljungdahl, W., and Subtelny, F. 1964. Remotation-
ized and other polynuclear hydrocarbons in
Matsunura, N., Kawashima, T., Marone, R., Ogaki,
and mutagenic properties of some volatile com-
ponents from a tryptophan pyrolysis. Science
207: 546.
Matsuno, Y., Chi, E., Lamasco, E., and Ames, B.
1975. Detection of mutagens as inorganic
Parisi, M. W. 1982. Mutagens and carcinogens
in cooked, smoked and charred foods. Oncology
Overview, Franklin Institute, in press.
Parisi, M. W., Ashih, S. H., Chi, F. S., and Lord,
D. B. 1979a. Effects of temperature and
time on mutagen formation in pan-fried ham-
1979b. Mutagens in heat-processed meat, bak-
17: 429.
phorbol diesters and hydrogenated on 3-nitroaminoimidazole-induced hepatic tu-
morogenesis in the rat. Fed. Proc. Trans. 36:
93.
Scheibe, D., and Dries, B. 1978. Tumor initia-
tion and promotion. Int. Rev. Exp. Path. 16:
127.
Formation of mutagens in cooked foods. J. Beef
Cancer Lett. 7: 169.
Sprague, N. E., Blum, S. A., and Wadsworth, J.
Cancer Lett. 9.
Sumita, T. 1976. Let's be scientific about the
problem of mutagens in cooked foods. Mutat.
Res. 40: 149.
Sumita, T., Kawahito, T., Nagai, M., Yabuki,
T., Seto, Y., Okamura, T., Shoji, R., Koyagi,
T., Taniguchi, K., Wakahashi, R., Itaka, Y.,
Jap. Acad. 53: 108.
Sumita, T., and Nagai, M. 1979. Mutagenic
factors in cooked foods. CRC Crit. Rev. Tox. 6:
189.
Takayama, S., Hisakawa, T., Tanaka, M., Katak,
Y., and Sumita, T. 1979. Transformation and
neoplastic development of hamster embryo
cells after exposure to tryptophan pyrolysis
products in tissue culture. In Naturally Occur-
ring Carcinogens-Mutagens and Modulators of
Carcinogenesis, ed. E. C. Miller et al. Univer-
sity Park Press, Baltimore, pp. 115-122.
Walker, D. W., Lisich, D. W., Leth, L. E., and
Proc. 35: 1071.
in mutagenic activity of pyrolysis products by
reaction with niacin. Mutat. Res. 65: 35.

Based on a paper presented during the IFT
Toxicology and Safety Evaluation Division's
program, "Mutagens in Cooked and Processed
Foods," at the 19th Annual Meeting of the Insti-
tute of Food Technologists, Atlantic City, N. J.

Acknowledgements. Research from the author's laboratory was supported in part by the College of Agriculture and Life Sciences, University of Wis-
con-Madison (CALS Research Division project number 3194), the University of Wisconsin-Mad-
sconsin Graduate School, the Wisconsin Agricultural Experiment Station, the United States Depar-
tment of Agriculture, the University of Wis-
con-Madison Food Research Institute, and NIH
research grant no. HHS-C456, awarded to the
National Cancer Institute, NIH.