
What's in the Beef?

Scientists Question the Safety
of Irradiated Ground Beef

A Special Report



Washington, DC
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Public Citizen, founded by Ralph Nader in 1971, is a non-profit research, lobbying and litigation organization based in Washington, D.C. Public Citizen advocates for consumer protection, and for government and corporate accountability.

The Center for Food Safety is a national, non-profit, membership organization established in 1997 to use science and the law to address increasing concerns over the impacts of the United States food production system on human health, animal welfare, and the environment.

What's in the Beef?

Research on irradiated foods and the effectiveness of the irradiation process dates to the 1950s. In the beginning, most research focused on the extent to which irradiation kills harmful microorganisms, and whether irradiated foods are palatable.

By and large, both of these questions have been satisfactorily answered: Foods “treated” with sufficient amounts of radiation can kill nearly all *E. coli*, *Salmonella*, *Listeria* and other pathogens found in food while leaving it edible, though perhaps with a scorched taste, unpleasant smell or discoloration.

In recent years, however, attention has turned toward questions of whether irradiated foods are toxic or could cause cancer, genetic damage or other health problems.

Irradiated foods fed to test animals have, indeed, been associated with a wide range of adverse health effects, including premature death, mutations and other genetic abnormalities, fetal death and other reproductive problems, a rare form of cancer, immune system disorders, fatal internal bleeding, organ damage, tumors, stunted growth and nutritional deficiencies.¹

Further, irradiation results in the formation of many chemical byproducts, some of which have toxic properties.

Perhaps most significantly, it was discovered in 1972 that irradiation of beef results in the formation of a class of chemicals known as 2-alkylcyclobutanones, or 2-ACBs.² Subsequent research determined that 2-ACBs are formed when certain fats – fats that are ubiquitous in food – are exposed to radiation.

These chemicals are so distinct from natural food components that they are used as “markers” to determine whether food has been irradiated. By the mid-1990s, the uniqueness of 2-ACBs to irradiated foods had been established.^{3,4,5,6,7,8,9,10,11,12}

Research then began into the question of whether these chemicals are toxic, or could cause cancer or genetic damage.

The results, preliminary as they may be, are of great concern. In several studies conducted over the past five years, 2-ACBs in their pure form have been associated with promoting colon cancer in rats, genetic damage in rats, and genetic and cellular damage in human and rat cells. The most recent and most extensive study was conducted by a team of German and French researchers working under a grant from the

European Union.^{13,14,15,16}

In the wake of these findings, Public Citizen and the Center for Food Safety hired a well-established food testing laboratory, Lebensmittel Consulting of Fostoria, Ohio, to test a variety of commercially available, irradiated ground beef products for the presence of 2-ACBs.

Materials and Methods

- Fresh, non-irradiated ground beef was purchased at a Safeway store in Washington, DC, and was tested raw and cooked.
- Fresh ground beef irradiated with an electron-beam irradiator by SureBeam Corp. was purchased at a Safeway store in Washington, DC, and a D'Agostino's store in New York City, and was tested raw and cooked.
- Pre-formed, frozen ground beef patties irradiated with a gamma-ray irradiator by Food Technology Service and sold under the "New Generation" label, was purchased at a Publix store in Hollywood, Fla., and was tested raw and cooked.
- Cooked hamburgers made from ground beef irradiated with an electron-beam irradiator by SureBeam Corp. of San Diego, were purchased at a Dairy Queen restaurant in Minneapolis. (*For detailed information on these companies, see p. 9*)

The meat was shipped to the laboratory in dry ice using standard shipping methods.

Patties with a thickness similar to the pre-formed New Generation patties were made with the non-irradiated beef and the fresh SureBeam irradiated ground beef. The patties were cooked in a skillet on each side until the meat was thoroughly browned on each side.

Two samples of each type of meat were analyzed, one by gas chromatography/mass spectrometry, and one by gas chromatography/flame ionization detection.

The Findings

The two types of 2-ACBs that have been associated with colon tumor promotion in rats, and with cellular and genetic damage in human cells were detected in all three irradiated ground beef products. These chemicals are 2-tetradecenylcyclobutaneone (2-tDeCB) and 2-tetracylcyclobutanone (2-tDCB).

A third type of 2-ACB associated with cellular and genetic damage in human cells was also detected in all three irradiated ground beef products. This chemical is 2-dodecylcyclobutanone (2-dDCB).

Among the three types of irradiated ground beef that had been cooked, SureBeam contained the highest levels of 2-tDeCB and 2-tDCB, while "New Generation" contained the highest level of 2-dDCB.

Among the two types of irradiated ground beef tested raw, "New Generation" contained the highest level of 2-tDCB and 2-dDCB, while SureBeam contained the highest level of 2-tDeCB.

No 2-ACBs were detected in the non-irradiated ground beef, whether raw or cooked. The absence of 2-ACBs in non-irradiated ground beef confirms the findings of numerous previous studies. (*See Notes 3-12.*)

Cooking of the irradiated beef generally, but not always, reduced the amount of 2-ACBs. (*See Table, next page.*)

Overall, 2-dDCB was detected in the greatest quantity, followed by 2-tDeCB and 2-tDCB.

The lead scientist at Lebensmittel Consulting speculated that the Dairy Queen hamburgers, though having the highest percentage of fat among the three irradiated types of beef, may have had the lowest levels of 2-ACBs due to the way they were cooked. Reasons for other variations in the results

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could not immediately be determined. The relationships between irradiation dose, fat content, cooking method and types of beef are not yet fully understood.

Discussion

In the European Union study, rats that drank solutions of 2-tDeCB and 2-tDCB, in conjunction with exposure to a known colon carcinogen, developed more large tumors, more multiple tumors, and more pre-tumorous lesions than rats only exposed to the carcinogen. Of the two chemicals, 2-tDeCB had a greater tumor promotion effect.

Additionally, in the European Union study, 2-tDeCB and 2-tDCB were detected in

small quantities in the adipose tissue (fat) and feces of the rats. But because most of the chemicals could not be accounted for, scientists have strongly recommended that more research be conducted into how the body metabolizes

2-ACBs. It is possible that the chemicals could be stored in other parts of the body, or could give rise to still other chemicals if the body breaks them down.

Because they have not been found to occur naturally in any food, 2-ACBs are known as “unique radiolytic products.” These chemicals are formed when certain “precursor” fatty acids are exposed to irradiation: 2-tDeCB is derived from oleic acid; 2-tDCB is

2-ACBs Detected in Irradiated Ground Beef

Beef type	2-dDCB ¹		2-tDeDCB ²		2-tDCB ³	
	micrograms per gram ⁴ of		micrograms per gram of		micrograms per gram of	
	meat	fat	meat	fat	meat	fat
Non-irradiated, raw	0.0000	0.000	0.0000	0.000	0.0000	0.000
	0.0000	0.000	0.0000	0.000	0.0000	0.000
Non-irradiated, cooked	0.0000	0.000	0.0000	0.000	0.0000	0.000
	0.0000	0.000	0.0000	0.000	0.0000	0.000
SureBeam, raw #1	0.0612	0.72	0.0349	0.41	0.0058	0.1
	0.0663	0.78	0.0374	0.44	0.0056	0.096
SureBeam, cooked #1	0.0544	0.64	0.0062	0.073	0.0007	0.008
	0.0621	0.73	0.0086	0.101	0.0009	0.01
SureBeam, raw #2	0.0331	0.57	0.0081	0.14	0.0008	0.014
	0.0307	0.53	0.0050	0.087	0.0008	0.013
SureBeam, cooked #2	0.0296	0.51	0.0081	0.14	0.0020	0.034
	0.0278	0.48	0.0075	0.13	0.0017	0.03
New Generation, raw	0.0975	1.5	0.0039	0.06	0.0054	0.093
	0.1040	1.6	0.0035	0.054	0.0058	0.1
New Generation, cooked	0.0910	1.4	0.0018	0.027	0.0012	0.02
	0.0832	1.28	0.0016	0.025	0.0008	0.013
Dairy Queen, cooked	0.0178	0.081	0.0003	0.0015	0.0002	0.004
	0.0185	0.084	0.0003	0.0012	0.0002	0.004

¹ Dodecylcyclobutanone

² Tetradecenylcyclobutanone

³ Tetradecylcyclobutanone

⁴ parts per million (ppm)

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derived from stearic acid; and 2-dDCB is derived from palmitic acid. (See *Table, next page.*)

Although the tests commissioned by Public Citizen and The Center for Food Safety only assessed the presence of 2-ACBs in irradiated ground beef, other researchers have detected the chemicals in many other irradiated foods: chicken, pork, lamb, eggs, duck, peanuts, mangoes, papayas, mangoes, freshwater tilapia, and saltwater mullet. (See *Notes 3-12.*)

The fatty acids that serve as precursors to 2-ACBs occur in virtually all foods that contain even a very small amount of fat. These foods include many that the Food and Drug Administration has legalized for irradiation, including red meat, poultry, fruit, vegetables and eggs. These foods also include many that the FDA is considering for legalization, including shellfish and ready-to-eat foods. Among the foods that contain oleic, stearic and palmitic acids are:

- *Red meat* – beef, pork, lamb, veal.
- *Poultry* – chicken, turkey, duck, goose, pheasant, chicken eggs.
- *Shellfish* – crab, oysters, shrimp.
- *Fruit* – apple, apricot, avocado, banana, blueberry, cherry, currant, fig, grapefruit, grape, guava, lemon, mango, olive, orange, papaya, peach, pear, pineapple, plum, raspberry, strawberry, tangerine.
- *Vegetables* – potato, tomato, pepper, cabbage, cauliflower, turnip, cucumber, pumpkin, pea, soybeans, sweet potato, corn.
- *Ready-to-eat foods* – pizza, frozen meals, peanut butter, raisins, granola bars, cake,

cookies, oatmeal and potato chips.¹⁷

Without knowing the types and levels of 2-ACBs in irradiated forms of these and other foods, toxicologists can only guess at the potential toxicity risks they could pose to humans who eat them.

Words of Caution

Members of the European Union research team concluded:

“[I]t seems not appropriate to draw a final conclusion concerning the risk associated with human consumption of irradiated fat-containing foods. However, since our results point towards toxic, genotoxic and even tumor promoting activity of certain 2-ACB, we strongly recommend to carry out further research, including confirmation of our results by other laboratories, to elucidate a possible risk associated with the consumption of irradiated fat-containing foods... To characterize the potential risk, hazards need to be identified, the exposure, the exact dose-response and particularly the kinetics and metabolism of 2-ACB in the living organism should be elucidated. All these studies are deemed necessary to gain insight into the mechanisms of the toxic effects. Numerous

questions still remain to be answered, and much research is left to be done, before a qualified risk assessment can be performed.”¹⁸

Additionally, the scientists stated:

2-ACB Byproducts of Irradiated Fatty Acids

Oleic¹ 2-tetradecylcyclobutanone (2-tDeCB)
Stearic² 2-tetradecylcyclobutanone (2-tDCB)
Palmitic³ 2-dodecylcyclobutanone (2-dDCB)

¹ Oleic acid (C_{18:1}) is a monounsaturated fatty acid

² Stearic acid (C_{18:0}) is a saturated fatty acid

³ Palmitic acid (C_{16:0}) is a saturated fatty acid

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“The relevancy of these results for the risk assessment of human consumption of irradiated food remains to be elucidated... In light of the expected extended application of food irradiation, however, it seems necessary to further clarify the potential toxicity of 2-ACBs and their contribution to a possible risk associated with human consumption of irradiated fat-containing food.”¹⁹

Further, the scientists stated:

“[W]e feel that our new data ... raise some doubts or at least suggest that caution should be exercised before any risk to consumers by exposure to these compounds is denied... It needs to be shown that despite the presence of potentially cyto- and genotoxic radiation-induced agents, the consumption of irradiated fat-containing food is safe for consumers.”²⁰

Earlier this year, the U.S. Department of Agriculture lifted the ban on serving irradiated ground beef as part of the National School Lunch Program. European Union research team member Francis Raul, Ph.D., of Louis Pasteur University in Strasbourg, France, was quoted in *The New York Times* of Oct. 15, 2003 as saying: “It is perhaps too early to start irradiating beef to give to children.”

Independent experts echo the concerns of the European Union research team.

Professor William W. Au, Ph. D., of the Department of Preventive Medicine at the University of Texas Medical Branch in Galveston, TX, stated:

“[In the European Union study on rats,] a portion of the [2-ACBs]

crossed the intestinal barrier, entered the blood stream and accumulated in adipose tissue of the animal. Therefore, consumption of irradiated food for a long time can cause significant accumulation of the toxic 2-ACB in the adipose tissues of consumers... [C]onsumption of an improper diet together with food that contains 2-ACB which acts as a tumor promoter can increase the risk for the development of colon cancer. Under this scenario, individuals who would normally outlive the risk for colon cancer might develop the cancer from the promoting effect of 2-ACB. Without a systematic investigation in the population, this serious concern has not been addressed yet... Short-term safety evaluation of components of irradiated food products, rather than on whole food, needs to be systematically conducted. Therefore, regulatory agencies and industries need to ensure that the irradiation process will not produce serious and long-term health effects to consumers.”²¹

Chinthalapally V. Rao, Ph. D., of the Division of Nutritional Carcinogenesis at the Institute For Cancer Prevention in Valhalla, New York, one of the leading cancer research centers recognized by the National Institutes of Health stated:

“[F]urther investigations are warranted to identify and assess the exact levels at which [2-ACBs] may exert tumor promoting effects. Also, a full-length study investigating the cancer promoting effects of 2-alkylcyclobutanones in irradiated foods (*per se*) and their mechanism(s) of action, is urgently

needed to address public health concerns. A thorough investigation of the effect of 2-alkylcyclobutanones at levels consumed by the human population and in models (*in vitro* and *in vivo*) of various types of cancers is warranted before proposing that irradiated foods do or do not promote colon cancer.”²²

The FDA's Position

For more than 15 years, the FDA has asserted that the chemical byproducts formed in irradiated foods are identical or similar to natural food components.

This assertion has been made on several occasions in the *Federal Register*, the official record of the U.S. government:

“[R]adiolytic products are typically identical to substances that occur naturally in foods.”²³ (Stated in 1997, when the FDA rejected citizens’ requests to suspend the legalization of irradiation for poultry.)

“There is no evidence, or any reason to believe, that the toxicity or carcinogenicity of any unique radiolytic products is different from that of other food components.”²⁴ (Stated in 1987, when the FDA rejected citizens’ requests to suspend the legalization of irradiation for fruit, vegetables and pork.)

“Because any [radiolytic products] are likely to be toxicologically similar to other food components, it would be virtually impossible to detect potential toxicological properties of these substances.”²⁵ (Stated in 1986, when the FDA legalized irradiation for fruit and vegetables.)

With the discovery of 2-ACBs, and the revelation that these chemicals are cancer promoters and have other toxic properties, these assertions made by the FDA are no longer true. There is now ample evidence that 2-ACBs do not occur naturally in non-irradiated food, and that they do have toxic properties.

In addition to the potential hazards posed by 2-ACBs, red meat consumption is a well-known risk factor for a myriad of health problems. Further, grilling coats beef with polycyclic aromatic hydrocarbons, known carcinogens.²⁶ And, grilling creates heterocyclic amines, which are mutagens and carcinogens associated with respiratory tract cancers (from the fumes), and are known colon carcinogens.^{27,28,29}

Clearly, the tumor promotion effects of 2-ACBs in irradiated ground beef must be investigated as to whether they act synergistically with these known colon carcinogens when hamburgers are grilled.

Finally, one published study has found that irradiation doubles the amount of *trans* fat in irradiated compared to non-irradiated ground beef.³⁰ Well-established nutrition science suggests that doubling of *trans* fat will increase the risk of chronic heart disease associated with this harmful fat.³¹ Further, an increase in *trans* fat also increases the risks of a variety of other human health problems, including increasing levels of LDL (“bad”) cholesterol and decreasing levels of HDL (“good”) cholesterol.^{32,33} The FDA must investigate this issue fully.

Recommendations

Public Citizen and The Center for Food Safety make the following recommendations:

- Based on the toxicity risks outlined above, and the potential *trans* fat increase, the FDA should promptly rescind its 1997 approval of irradiation for beef.

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- Currently, the FDA is considering petitions to legalize irradiation for “ready-to-eat” foods (which comprise 37 percent of the typical American’s diet); crustacean shellfish (such as crabs, shrimp and lobsters); molluscan shellfish (such as clams, oysters and mussels); and certain red meat products. The FDA is also considering a petition to increase the maximum allowable irradiation dose for poultry. The FDA should refrain from legalizing irradiation for any of these or additional types of food until comprehensive, published, peer-reviewed research is conducted into the potential carcinogenicity, genotoxicity and overall toxicity of 2-ACBs that are known or suspected to be present in foods covered by pending before the FDA. This must include assessing synergistic effects, such as assessing the tumor promotion effect of certain 2-ACBs in combination with pre-existing carcinogenic properties that may be associated with such foods.

- The FDA should calculate a 100-fold safety factor for 2-ACBs, which, in the absence of an alternative safety factor justified by evidence, the U.S. Code of Federal Regulations requires must be calculated before a

food additive can be legalized for human consumption. (This safety factor is calculated by establishing the highest level at which no adverse health effect is detected, and dividing that figure by 100.) If hazardous levels of 2-ACBs are detected in foods for which irradiation already has been legalized, these rulings should be rescinded. Likewise, if hazardous levels of 2-ACBs are detected in foods for which irradiation is being considered, these petitions should be denied.

- The U.S. Department of Agriculture, with FDA concurrence, should reverse its decision to allow irradiated ground beef to be served as part of the National School Lunch Program and other nutritional programs until the open issues related to 2-ACBs and other chemicals formed in irradiated beef are sufficiently addressed. Further, the FDA and USDA should recall all irradiated ground beef in distribution. Using our schoolchildren as guinea pigs in a massive uncontrolled feeding experiment – the largest ever conducted anywhere in the world with any irradiated foods – defies common sense and would be immoral until the scientific safety issues are resolved.

Company Information

- **Safeway**, based in Pleasanton, CA, has more than 7,000 stores in the United States and Canada. Irradiated, fresh ground beef is reportedly on sale in about 135 stores in Delaware, Maryland, Virginia and Washington, D.C.

- **D’Agostino’s**, based in Larchmont, N.Y., has about 25 stores in the New York City area. Irradiated, fresh ground beef is reportedly on sale at all stores.

- **Dairy Queen**, based in Edina, Minn., has about 6,000 restaurants in the United States, Canada and 20 other countries. Irradiated hamburgers are reportedly on sale in Minnesota, South Dakota, and

certain parts of the Northeast and Southwest.

- **Publix**, based in Lakeland, Fla., has more than 700 stores in Alabama, Florida, Georgia, South Carolina and Tennessee. Irradiated, frozen ground beef patties are reportedly on sale in all stores.

- **SureBeam**, based in San Diego, irradiates food with linear accelerators that emit electrons nearly to the speed of light.

- **Food Technology Service**, based in Mulberry, FL, near Tampa, irradiates food with gamma rays projected from radioactive cobalt-60.

Notes

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