Cancer Risk from Nitrosamines in Pork Bacon

Prepared by:

Risk Assessment and Analytics Staff
Office of Public Health Science
Food Safety and Inspection Service
U.S. Department of Agriculture

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1. Summary

The excess lifetime cancer risk, which is the additional risk beyond the background cancer risk, resulting from five major nitrosamines in bacon was calculated to be 1.46×10^{-6} (or about 1 in 683,000). Recent (2013) nitrosamine concentration data was provided by the USDA Agricultural Research Service and the risk estimate was derived using the *EPA Guidelines for Carcinogen Risk Assessment*.

2. Introduction

The chemicals known as *N*-nitroso compounds or nitrosamines are reaction products of nitrogen oxides (e.g. nitrites and nitrates) and amino groups. Nitrites are added to a variety of cured meats, including bacon, to prevent both spoilage and toxin formation from *Clostridium botulinum*, and to improve the flavor and appearance of the meat. Fried bacon is one of the most significant dietary sources of nitrosamines (Lijinsky 1999), as reaction of nitrite with amines and amino acids in the meat occurs during cooking and yields volatile nitrosamines (Glória et al. 1997). Unlike non-volatile nitrosamines, most of the volatile nitrosamines, such as nitrosodimethylamine, nitrosopyrrolidine, and nitrosopiperidine are carcinogenic (Dietrich et al. 2005).

The USDA Agricultural Research Service (ARS) conducted a pilot study to measure the levels of nitrosamines in pork bacon measured in the fall of 2013. The average nitrosamine levels determined by that study were combined with average pork bacon consumption data to estimate the excess lifetime cancer risk from consuming such bacon. It is important to note that the assessment considered only nitrosamine exposure from pork bacon, even though nitrosamines are found in other food items, including other cured meats and smoked fish. Moreover, the available data did not correlate the levels of nitrosamines found in bacon with the amount of nitrites originally added during the curing process. While permissible levels of nitrites that can be added to bacon are prescribed by FSIS regulations, the actual amount of nitrites added to a given production lot of bacon is unknown. Therefore, the excess lifetime cancer risks calculated in this assessment are based on typical levels of nitrosamines found in bacon and no inference can be drawn regarding the underlying risk of adding various levels of nitrites to bacon.

3. Risk Equation

The cancer risk calculation based on the 2005 U.S. Environmental Protection Agency *Guidelines for Carcinogen Risk Assessment* (EPA 2005 and EPA/OSWER 2009) was used to estimate excess lifetime cancer risk from nitrosamines in bacon.

$$Risk = C \cdot 10^{-6} \cdot \frac{IR}{BW} \cdot SF \qquad \text{(Eq. 1)}$$

Table 1: Factors in the risk equation

Symbol	Description	Units
Risk	Excess lifetime cancer risk	-
C	Nitrosamine concentration in bacon	ng/g
10^{-6}	Conversion factor	mg/ng
IR	Bacon ingestion rate and body weight. This assessment used a single combined variable (*IR/BW*).	g/kg/day
BW		
SF	Cancer slope factor	$(mg/kg/day)^{-1}$

4. Input data

4.1 Nitrosamine concentration in bacon (*C*)

Staff from all three FSIS Laboratories collected a total of 42 packages of cured or regular (i.e. not "uncured" or "nitrate free") pork bacon from retail outlets. These samples were shipped to the ARS laboratory in Wyndmoor, Pennsylvania, and analyzed for five nitrosamines using the QuEChERS analytical method. Prior to analysis, the bacon was fried at 340-345 °F for 3 minutes on each side, in accordance with the protocol provided by the FSIS Eastern Lab. Mean concentrations for each of the five nitrosamines are given in Table 2.

Table 2: Nitrosamine levels in fried bacon
Non-Detects (ND) replaced with ½ the limit of detection (LOD) for calculation of mean and standard deviation.

	NDMA	**NDEA**	**NPYR**	**NPIP**	**NDBA**
Samples (n)	42	42	42	42	42
Range	0.22-1.38 ppb	nd-0.82 ppb	0.87-13.05 ppb	nd-1.33 ppb	0.54-2.04 ppb
Mean	0.52 ppb	0.17 ppb	3.38 ppb	0.27 ppb	1.11 ppb
St. Deviation	0.25 ppb	0.20 ppb	2.40 ppb	0.26 ppb	0.31 ppb
# of ND	0	24 (LOD 0.1 ppb)	0	21 (LOD 0.1 ppb)	0

4.2 Bacon ingestion rate (*IR/BW*)

Bacon consumption data were drawn from the 2007-2010 One-Day National Health and Nutrition Examination Survey / What We Eat in America (NHANES/WWEIA) dietary surveys. All food descriptions containing the word bacon were identified, and any items referring to beef bacon, turkey bacon, and meatless bacon were removed, leaving 54 food codes (see appendix). For each of these 54 items, an ingredient fraction reflecting the total amount of pork meat and pork fat in the food item was applied. These ingredient fractions were taken from the 2003-2006 WWEIA Food Commodity Intake Database (FCID) developed by the EPA, or the Food and Nutrition Database for Dietary Studies (FNDDS) developed by ARS. In a few cases, recipes were not available and recipes for very similar food items were used instead. It was assumed that all consumed bacon was cooked. Using the Foods Analysis and Residue Evaluation Program (FARE) version 10.06, mean bacon consumption for the U.S. population was estimated at 0.0216 grams of bacon per kilogram bodyweight per day.

4.3 Slope factor (*SF*)

The slope factor is a measure of the carcinogenic potential of a chemical compound. The greater the slope factor, the greater the cancer risk from ingesting a set amount of that compound. Of the eight nitrosamines identified in a systematic literature review as being of concern in bacon (see Stuff et al. 2009), four have oral slope factors listed in the EPA Integrated Risk Information System (IRIS). A fifth, nitrosopiperidine (NPIP), has an oral slope factor listed in the California Office of Environmental Health Hazard Assessment (OEHHA) Toxicity Criteria Database. These five nitrosamines and their oral slope factors were included in this assessment. The other three nitrosamines whose concentrations were given by Stuff et al. (2009) can be described as low-risk (see Table 3).

Table 3: Slope factors for selected nitrosamines		
Nitroso-	**Oral slope factor** $(mg/kg/day)^{-1}$	**Notes**
--dimethylamine (NDMA)	51	Source: EPA IRIS
--pyrrolidine (NPYR)	2.1	Source: EPA IRIS
--piperidine (NPIP)	9.4	Source: California OEHHA
--diethylamine (NDEA)	150	Source: EPA IRIS
--dibutylamine (NDBA)	5.4	Source: EPA IRIS
--proline (NPRO)	-	IARC Group 3 ("not classifiable as to its carcinogenicity to humans"). Referred to as non-carcinogenic by Lijinsky (1999).
--thiazolidine-4-carboxylic acid (NTCA)	-	Not listed by IARC. NTCA is "likely to be of little importance as far as its oncogenic properties are concerned." (Lin and Gruenwedel 1990).
--thiazolidine (NTHZ)	-	Not listed by IARC. Referred to as non-carcinogenic by Lijinsky (1999).

5. Risk characterization and discussion

Using Equation 1, excess lifetime cancer risk was calculated separately for each of the five nitrosamines and then summed to arrive at a total excess lifetime cancer risk of 1.46×10^{-6} (or about 1 in 683,000) due to average population exposure to nitrosamines through pork bacon.

To put this risk into context, the EPA generally regulates or makes recommendations to stay within a 10^{-6} to 10^{-4} excess risk range, depending on statute (Dr. R. Schoeny, personal communication, July 6, 2012). The EPA Office of Pesticide Programs considers 3×10^{-6} average population cancer risk as "acceptable" (Deborah Smegal, FDA (formerly EPA), personal communication, Jan. 2, 2014).

6. Reviews

The methodology used in this assessment was reviewed as part of an earlier version (Jan. 10, 2013). Compared to the earlier version, this version incorporates newer nitrosamine concentration data and bacon consumption data. The earlier version was completed by Alexander Domesle, Dr. Wayne Schlosser, and Dr. David LaBarre (all FSIS) and reviewed by the Interagency Risk Assessment Consortium (IRAC), as well as:

1. Dr. Jade Mitchell-Blackwood (FSIS)
2. Dr. Eric Ebel (FSIS)
3. Dr. Kerry Dearfield (FSIS)
4. Dr. Rita Schoeny (EPA)
5. Dr. Clark Carrington (FDA)
6. Dr. Rosalie Elespuru (FDA)
7. Dr. John Johnston (FSIS)

7. References

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Appendix: NHANES/WWEIA Food Codes used for Consumption Analysis

Food Code, Fraction designated as bacon

22600100, 0.222
22600200, 0.994
22601000, 0.994
22601020, 0.994
22601040, 0.994
22602010, 0.994
22605010, 0.989
27446315, 0.035
27446320, 0.035
27510360, 0.088
27510390, 0.065
27510400, 0.094
27510425, 0.088
27510430, 0.058
27510435, 0.038
27510440, 0.052
27513060, 0.146
27520120, 0.057
27520130, 0.067
27520135, 0.067
27520140, 0.074
27520150, 0.101
27520160, 0.184
27520165, 0.037
27520166, 0.037
27520170, 0.140
28321130, 0.203
32105030, 0.283
32105080, 0.145
32105081, 0.145
32105082, 0.145
32105085, 0.114
32202000, 0.061
32202070, 0.094
32202075, 0.123
32202080, 0.108
32202085, 0.051
32202090, 0.050
35002000, 0.130
41310220, 0.106
41601020, 0.035
58127290, 0.097
58127350, 0.046
71402505, 0.154
71411000, 0.154
71508060, 0.026
71508070, 0.033
75144100, 0.090
75145000, 0.027
76601000, 0.040
76601010, 0.040
76601020, 0.040
83101500, 0.096
83101600, 0.031