

March 22, 2002

Interpretation of the Risk Estimates for Intact and Non-Intact Beef Cooked to Temperatures 140 °F

On March 18, 2002, the Office of Public Health and Science presented the findings of the comparative risk assessment for *E. coli* O157:H7 in intact (non-tenderized) and non-intact (tenderized) beef. At the conclusion of this presentation, the Office of Policy, Program Development and Evaluation (OPPDE) requested estimates of the expected risk of illness per serving from *E. coli* O157:H7 for non-intact (tenderized) and intact (tenderized) beef cooked to internal temperatures of 140 °F or less.

Tables 1 and 2 provide estimates of the risk of illness per serving for the general and susceptible populations^[1] given that each serving consisted of 3.2 cm-thick steaks (intact or non-intact) cooked to temperatures 140 °F by either grilling, frying or broiling, and contaminated with either 1 or 1,000 *E. coli* O157:H7. These two bacterial contamination levels were chosen because: (1) the non-intact beef risk assessment suggests that a single *E. coli* O157:H7 organism in contaminated steaks prior to cooking occurs 98% of the time in the most likely scenario, and (2) NACMCF assumed 1,000 *E. coli* O157:H7 organisms to be a worst case contamination level in its deliberations of the risk of illness for non-intact beef. The estimates for the risk of illness per serving for the general U.S. population are based on the most likely dose-response curve derived in the non-intact beef risk assessment. The estimates for the risk of illness per serving for the susceptible U.S. population are based on the upper bound dose-response curve.^[2]

The risk estimates provided in this memo illustrate most likely and worst case scenarios for servings of non-intact and intact steaks. A complete set of estimates that consider alternative steak thicknesses (1.3 and 1.9 cm) and initial *E. coli* O157:H7 contamination levels (e.g., 10 and 100 *E. coli* O157:H7 organisms) are contained in Addendum 1.^[3] For information on analyses of the primary data used in this risk assessment, see Addendum 2.

Table 1. Risk of Illness Among the Less-susceptible Population for Steaks Cooked to Temperatures 140°F

| | | Expected Illness per Serving for the Less-susceptible Population Based on an Initial Contamination Level of 1 <i>E. coli</i> O157:H7 Organisms Prior to Cooking | | |
|-------------------------|-------------------|--|--------------|------------|
| Temperature (°F) | Type | Broil | Grill | Fry |
| 110 | Non-intact | 1.48E-03 | 2.04E-03 | 2.34E-03 |
| | Intact | 1.48E-03 | 1.94E-03 | 2.19E-03 |
| 120 | Non-intact | 9.36E-05 | 6.08E-04 | 1.13E-03 |
| | Intact | 9.36E-05 | 4.75E-04 | 8.47E-04 |

| 130 | Non-intact | 7.56E-08 | 6.49E-05 | 3.63E-04 |
|--|------------|----------|----------|----------|
| | Intact | 7.56E-08 | 3.03E-05 | 1.68E-04 |
| 140 | Non-intact | 0.00E+00 | 1.05E-06 | 6.14E-05 |
| | Intact | 0.00E+00 | 1.42E-07 | 1.09E-05 |
| Expected Illness per Serving for the Less-susceptible Population Based on an Initial Contamination Level of 1,000 <i>E. coli</i> O157:H7 Organisms Prior to Cooking | | | | |
| Temperature (°F) | Type | Broil | Grill | Fry |
| 110 | Non-intact | 3.12E-01 | 3.43E-01 | 3.57E-01 |
| | Intact | 3.12E-01 | 3.38E-01 | 3.50E-01 |
| 120 | Non-intact | 7.10E-02 | 2.22E-01 | 2.84E-01 |
| | Intact | 7.10E-02 | 1.98E-01 | 2.55E-01 |
| 130 | Non-intact | 7.56E-05 | 5.30E-02 | 1.73E-01 |
| | Intact | 7.56E-05 | 2.74E-02 | 1.09E-01 |
| 140 | Non-intact | 8.44E-13 | 1.04E-03 | 5.07E-02 |
| | Intact | 8.44E-13 | 1.42E-04 | 1.05E-02 |

Summary:

- The expected illnesses per serving for the general population for the most likely initial contamination level of 1 *E. coli* O157:H7 organism in contaminated steaks is lower for broiling than grilling and frying, decreases with increasing temperature, and is the same for non-intact and intact steaks that are broiled, but is lower in intact steaks that are either fried or grilled. For the general population, the expected illnesses per serving is very low (probability of less than 1 illness in a million servings consumed) for both intact and non-intact steaks that are broiled to an internal temperature of 130 °F, or for intact steaks grilled to an internal temperature of 140 °F.
- The expected illnesses per serving for the general population for the worst case contamination level of 1,000 *E. coli* O157:H7 organisms follows the same trends as those found for the most likely contamination level. The expected number of illness per serving is at least 100-fold greater if the steaks are initially contaminated with 1,000 *E. coli* O157:H7 organisms rather than the most likely contamination level of 1 *E. coli*

O157:H7 organism. Among the general population, grilling and frying steaks to an internal temperature of 140 °F results in expected illnesses per serving between 1 illness in 100 fried steaks consumed and 1 illness in 10,000 grilled steaks consumed. Steaks (regardless of whether they are intact or non-intact) that are broiled to an internal temperature of 140 °F are reasonably safe.

Table 2. Risk of Illness Among More-susceptible Populations for Steaks Cooked to Temperatures 140 °F

| | | Expected Illness per Serving for the More-susceptible Populations Based on an Initial Contamination Level of 1 <i>E. coli</i> O157:H7 Organisms Prior to Cooking | | |
|-------------------------|-------------------|---|--------------|------------|
| Temperature (°F) | Type | Broil | Grill | Fry |
| 110 | Non-intact | 1.40E-02 | 1.91E-02 | 2.18E-02 |
| | Intact | 1.40E-02 | 1.82E-02 | 2.04E-02 |
| 120 | Non-intact | 9.03E-04 | 5.82E-03 | 1.07E-02 |
| | Intact | 9.03E-04 | 4.56E-03 | 8.07E-03 |
| 130 | Non-intact | 7.30E-07 | 6.26E-04 | 3.48E-03 |
| | Intact | 7.30E-07 | 2.93E-04 | 1.62E-03 |
| 140 | Non-intact | 8.22E-15 | 1.01E-05 | 5.93E-04 |
| | Intact | 8.22E-15 | 1.37E-06 | 1.05E-04 |
| | | Expected Illness per Serving for the More-susceptible Populations Based on an Initial Contamination Level of 1,000 <i>E. coli</i> O157:H7 Organisms Prior to Cooking | | |
| Temperature (°F) | Type | Broil | Grill | Fry |
| 110 | Non-intact | 7.23E-01 | 7.51E-01 | 7.62E-01 |
| | Intact | 7.23E-01 | 7.46E-01 | 7.56E-01 |
| 120 | Non-intact | 3.57E-01 | 6.28E-01 | 6.96E-01 |
| | Intact | 3.57E-01 | 5.97E-01 | 6.66E-01 |

| | | | | |
|-----|------------|----------|----------|----------|
| 130 | Non-intact | 7.29E-04 | 2.99E-01 | 5.62E-01 |
| | Intact | 7.29E-04 | 1.90E-01 | 4.49E-01 |
| 140 | Non-intact | 8.15E-12 | 9.92E-03 | 2.91E-01 |
| | Intact | 8.15E-12 | 1.37E-03 | 8.74E-02 |

Summary:

- The expected illnesses per serving for the susceptible population for the most likely initial contamination level of 1 *E. coli* O157:H7 organism in contaminated steaks is lower for broiling than grilling and frying, decreases with increasing temperature, and is the same for non-intact and intact steaks that are broiled, but is lower in intact steaks that are either fried or grilled. For the susceptible population, the expected illnesses per serving is very low for both intact and non-intact steaks broiled to an internal temperature of 140 °F (probability of less than 1 illness in a million servings) and for intact steaks grilled to an internal temperature of 140 °F (probability of about 1 illness in a million servings)
- The expected illnesses per serving for the susceptible population for the worst case contamination level of 1,000 *E. coli* O157:H7 organisms follows the same trends as those found for the most likely contamination level. The expected number of illness per serving is at least 10-fold greater if the steaks are initially contaminated with 1,000 *E. coli* O157:H7 organisms rather than the most likely contamination level of 1 *E. coli* O157:H7 organism. For the susceptible population, grilling and frying steaks to an internal temperature of 140 °F still results in a substantial frequency of illness between 3 illnesses in 100 fried non-intact steaks consumed and 9 illness in 1,000 grilled non-intact steaks consumed.

Survival of *E. coli* O157:H7 on the Surface of Intact Steaks

In addition to the estimates for the risk of illness per serving of intact and non-intact steaks, OPPDE asked why there is any risk at all from *E. coli* O157:H7 on intact steaks since it is assumed that all bacteria would be destroyed during cooking. First, the only empiric evidence available (Sporing 1999, KSU study) does not support this assumption. In fact, the Kansas State University (KSU) study shows very limited log reductions at low cooking temperatures regardless of whether or not the steak is tenderized. Second, thermal destruction of bacteria is a probabilistic phenomenon. The fraction of *E. coli* O157:H7 remaining after cooking can be estimated for any given temperature. Generally, this fraction of bacteria decreases with increasing cooking temperature. But for some cooking temperatures this fraction never equals zero. Third, the remaining level of surface *E. coli* O157:H7 depends on the initial level of contamination, the cooking method, and the duration of cooking as indicated in the analysis of the Kansas State University data included in the non-intact beef risk assessment (see Addendum 2 for a summary of this analysis).

Addendum 1.

See the accompanying Excel spreadsheet titled: "Addendum 1: Risk Estimates" at http://www.fsis.usda.gov/Science/Risk_Assessments/index.asp.

Addendum 2.

Trends Observed in the Data from the Kansas State University Thesis (Spring, 1999)

- **Cooking Method.** Broiling was more effective in reducing the level of *E. coli* O157:H7 in both non-intact (tenderized) and intact (non-tenderized) beef steaks, regardless of steak thickness or temperature, than either grilling or frying. Cooking effectiveness by method: broiling > grilling > frying.
- **Duration of Cooking for each Method.** Broiling required less time to achieve the internal temperature than either grilling or frying. Cooking effectiveness by duration: broiling < grilling < frying
- **Duration of Cooking by Steak Thickness.** Thicker beef steaks took longer than thinner steaks to attain the desired internal temperature. Effect of steak thickness on time to achieve internal temperature: 3.2 cm > 1.9 cm > 1.3 cm
- **Effect of Cooking in Reducing *E. coli* O157:H7 for Non-intact (Tenderized) Compared to Intact (non-Tenderized) Beef Steaks.**
 - **Broiling.** There was no difference in the reduction in the level of *E. coli* O157:H7 in intact (non-tenderized) compared to non-intact (tenderized) beef steaks that were broiled, regardless of temperature (range: 110-160 °F). Note: For the 1.9 cm beef steaks, however, there was a greater reduction in the level of *E. coli* O157:H7 in intact (tenderized) compared to non-intact beef steaks. This is likely to have been an artifact of the data.
 - **Grilling.** There was a slightly greater reduction in the level of *E. coli* O157:H7 in intact (non-tenderized) compared to intact (tenderized) 1.9 cm and 3.2 cm-thick beef steaks at all temperatures (110-160 °F). For thinner steaks (1.3 cm), the reduction in the level of *E. coli* O157:H7 was the same for non-intact (tenderized) as intact (tenderized) steaks for all temperatures (110-160 °F).
 - **Frying.** At all cooking temperatures (110-160 °F), there was a greater reduction in the level of *E. coli* O157:H7 in all intact (non-tenderized) compared to intact (tenderized) steaks. This trend was more apparent at higher temperatures and as the steak thickness increased.

Explanation of Cooking Effectiveness Trends:

Broiling was more effective than all other cooking methods in reducing the level of *E. coli* O157:H7 on the surface and interior of steaks than either grilling or frying even though the cooking duration was shorter. There are two plausible explanations, one for surface *E. coli* O157:H7 and another for interior *E. coli* O157:H7. First, broiling is more likely to kill the *E. coli* O157:H7 on the surface of steaks than other methods because of the high temperature of the heating element (e.g., contact with an open flame/intense radiated heat) compared to grilling (e.g., less contact with a flame) and frying (e.g., heat is evenly distributed across the skillet). Second, broiling is also more likely to kill *E. coli* O157:H7 in the interior of the steaks than other methods because once the internal temperature is reached, the surface is significantly hotter (e.g., due to the type of heating element) and therefore the temperature continues to rise even after removed from the broiler (as indicated in the Sporing thesis). As a result, the internal temperature for broiled steaks was likely to be higher than reported.

^[1] The estimates of the risk of illness for the general U.S. population are based on the most likely dose-response curve in the non-intact beef risk assessment. The estimates for the risk of illness for susceptible individuals in the U.S. population (e.g., children, elderly, and immunocompromised) are based on the upper bound dose-response curve in the non-intact beef risk assessment.

^[2] The most likely dose-response curve in the non-intact beef risk assessment is based on the most likely dose-response curve estimated from a FSIS ground beef risk assessment. This curve was adjusted in light of human outbreak data from the U.S. and Japan. The upper bound dose-response curve in the non-intact beef risk assessment is similarly derived. It envelops the outbreak data and implies a higher fraction ill at each dose relative to the most likely curve.

^[3] There were numerous risk estimates from the non-intact beef risk assessment, one for each combination of cooking method, cooking temperature, steak thickness, initial level of *E. coli* O157:H7 contamination, and whether or not the steak was tenderized. As a result, the complete set of risk estimates for Addendum 1 are provided as an accompanying Excel spreadsheet, titled: "Addendum 1 : Risk Estimates" at http://www.fsis.usda.gov/Science/Risk_Assessments/index.asp

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