Color of Cooked Ground Beef as It Relates to Doneness

The Food Safety and Inspection Service (FSIS) of the U.S. Department of Agriculture (USDA) has conducted a longstanding consumer education program on safe cooking and handling of meat and poultry. Proper food safety practices prevent situations that promote bacterial growth, cross-contamination, and foodborne illness. Thorough cooking destroys bacteria.

FSIS has long advised consumers to use a food thermometer when cooking meat and poultry to ensure that a temperature sufficient to destroy bacteria has been reached. In June 1997 FSIS expanded this recommendation to include ground beef patties. Pathogens (including *Salmonella* and *Escherichia coli* O157:H7) die when exposed to heat for a specific amount of time. A ground beef patty cooked to 160 °F is safe.

E. coli O157:H7 is a strain of bacteria that produces a toxin that can cause hemorrhagic colitis. This illness can develop into an extremely serious condition known as hemolytic uremic syndrome, which can cause kidney failure, brain damage, strokes, and seizures in young children and the elderly. *E. coli* O157:H7 has caused numerous sporadic cases as well as outbreaks of foodborne disease resulting in illnesses and deaths. This pathogen can survive both refrigerator and freezer storage. A number of *E. coli* O157:H7 outbreaks recorded since 1982 have been linked to **undercooked** ground beef as the primary source of infection.

The 1993 Western states outbreak of *E. coli* O157:H7 attributed to undercooked hamburgers served at a fast-food chain was a turning point. The outbreak sickened hundreds and was responsible for four deaths. While it was not the first outbreak of foodborne illness that the United States had experienced, it was a particularly difficult one for the public to accept; many young children became ill, and the food source was the traditional American hamburger.

In 1994, as a response to the outbreak, the USDA declared *E. coli* O157:H7 an adulterant in raw ground beef and initiated a monitoring program for *E. coli* O157:H7 in raw ground beef (testing confirmed that contamination occurs sporadically and at low levels). FSIS also initiated a program to encourage better controls and testing by industry, and required safe food handling labels on all raw meat and poultry products.

While working with industry to improve the safety of the food supply, FSIS has continued to promote food safety in the home. Since meat and poultry products can contain harmful bacteria, it is important that ground beef be cooked thoroughly. Future incidents of foodborne illness may be prevented if food handlers understand and act on a simple fact: **Thorough cooking to an internal temperature of 160 °F throughout kills *E. coli* O157:H7.**

Many food handlers and consumers believe that visible signs, such as color changes in the food, are indicators that the food is safely cooked. **However, recent research has shown that color and texture indicators are not reliable.** In particular, a 1995 study done by Kansas State University (Hunt et al, 1995) found that a sufficient number of ground beef patties were turning brown well before they reached 160 °F to make color an unreliable indicator of doneness. A consumer who believes a brown color always means a safe hamburger is taking a chance on foodborne illness.

Unfortunately data show that many consumers either do not own a food thermometer or rarely use one when cooking ground beef (FDA-CFSAN/USDA, 1998; Koeppl, 1998). Prior to June 1997, consumers who did not use a food thermometer were advised by FSIS to cook ground beef patties until the center and the cooked-out juices were no longer pink. Consumers were also advised to look for a firm "cooked" texture rather than a softer "raw or rare" texture in the
meat.

However, research results raised questions regarding the suggestions for the visual checks for doneness (Hague et al, 1994; Hunt et al, 1995). Consequently, in June 1997 USDA issued a press release advising consumers to use a food thermometer when cooking ground beef patties, and not to rely on the internal color of the meat. Rather, consumers should cook ground beef patties to 160 °F.

Color as an Indicator of Doneness

FSIS recognizes that there are two paradoxical problems with advice about using the color of ground beef to test for doneness and guarantee the destruction of pathogens:

1. Some ground beef may appear to have lost all pink color before it is fully cooked. If raw ground beef is somewhat brown already, it may look fully cooked before it reaches a safe temperature.
2. Some lean ground beef may remain pink at temperatures well above the 160 °F final cooking temperature recommended for consumers.

Browning Before a Safe Temperature is Reached

Cooked ground beef patties may appear brown before they reach a safe internal temperature. This is primarily caused by extensive oxidation of the fresh ground beef pigment and can occur, for example, with prolonged thawing of frozen ground beef, or refrigerator storage of thawed ground beef.

When ground beef is exposed to air, the ferrous iron in its myoglobin pigment is oxygenated to form a ferrous iron-oxygen complex. Myoglobin is a purplish-red color in its unoxygenated state, and becomes red when the iron complexes with oxygen to form oxymyoglobin. This is what gives fresh beef its red color. But if meat is stored for long periods of time, is stored above proper temperatures, or is exposed to too much air, the ferrous iron loses an electron to become ferric iron. The resulting ferric pigment, known as metmyoglobin, is brown.

Consumers associate bright red color with high quality (Lynch et al, 1986) and are frequently concerned when ground beef appears red on the outside and brown on the inside. Different levels of oxygenation at different locations inside and on the surface of the meat can account for this coloration (the grinding process allows air to contact more surface area of the meat). If ground beef loses contact with the air, as with the inside of the package of ground beef, it will turn grayish-brown. Likewise, as ground beef is stored, even for as little as one day, it might also turn prematurely brown (USDA-ARS/FSIS, 1998).

When ground beef is cooked, it changes color from red to pink to brown. If the meat is already brown, it will not change color during cooking. Recent research has shown some ground beef patties to look well-done at internal temperatures as low as 131 °F (Hague et al, 1994; Hunt et al, 1995; USDA-ARS/FSIS, 1998).

Raw meat from older carcasses can also be less red or darker in color, and can appear to be adequately cooked when it is actually still undercooked. When ground beef patties are made from a mix of older and younger carcasses, it has been found that the patties cooked to 131 °F are similar in color to patties cooked to 140 °F. Patties cooked to 150 °F have been shown to be visually indistinguishable from those

cooked to 160 °F (Hague et al, 1994).

After reviewing existing research, FSIS initiated its own study to survey the prevalence of premature browning in cooked ground beef. USDA researchers prepared and cooked patties from ground beef purchased from various locations across the country. More than 25 percent of the fresh ground beef patties turned brown prematurely ("prematurely" was defined as before reaching the safe temperature of 160 °F). USDA research results presented at a May 27, 1998, public meeting in Arlington, VA, reaffirmed the Agency's advice that color is an unreliable indicator of doneness. Consumers should use a food thermometer to be sure ground beef patties reach 160 °F (USDA-ARS/FSIS, 1998).

The USDA researchers found considerable variation both between and within beef patty formulations in endpoint temperature and color, even when controlled cooking procedures were followed. Therefore, unless a food thermometer is used when cooking ground beef patties, it is difficult for consumers to determine whether the patties are thoroughly cooked.

Persistent Pink Color in Cooked Meat Patties

There are several reasons why ground beef may remain pink at temperatures above 160 °F. This phenomenon is primarily associated with the pH and the level of pigment in the meat, as well as the fat content.

Normal fresh muscle has a pH ranging from 5.3 to 5.7. When thoroughly cooked, the myoglobin, oxymyoglobin, and metmyoglobin pigments of normal meat are converted (i.e. denatured) to denatured hemichrome, the grey pigment of cooked meat. Meat with a pH of 6.0 or higher can remain pink at 159.8 °F. The rate at which normal muscle pigments change to form the grey denatured hemichrome is affected by pH. The higher the pH, the longer the cooking time and/or higher the final internal temperature required for denaturation to be complete (Mendenhall, 1989). A high pH reduces the amount of myoglobin denatured by cooking, resulting in a pink color rather than the expected grey cooked color created by denatured hemichrome (Trout, 1989).

A high concentration of pigment also contributes to a red color in cooked meat. Meat coming from bulls typically exhibits both a higher pH and high concentrations of pigment. Mendenhall (1989) suggests that when patties are formulated from a mixture of bull meat, chuck, and beef trim with similar amounts of total pigment, there are significant differences in cooked internal color, indicating that the pH is responsible. But when pH is held constant, the concentration of total pigment contributes to the abnormal internal color. It was further shown that when cooked bull meat (pH 6.2) is compared to a mixture of bull meat, chuck, and trim (pH 6.2), the bull meat patty is significantly redder due to the higher concentration of pigment.

Most store-purchased ground beef is a mixture of meat from multiple sources (bulls, steers, cows, heifers) because ground beef is formulated to achieve a very specific fat content. Trimmings from many sources are combined.

A third factor affecting cooked ground beef color is the amount of fat in beef patties. Low-fat beef appears to have less conduction of heat than high-fat beef. Consequently, low-fat beef patties—including those that contain water, oat bran, carrageenan, and/or isolated soy protein—require longer cooking times and higher cooking temperatures to reach a certain internal temperature. Furthermore, patties can remain pink even though they have reached internal temperatures higher than the recommended 160 °F. In some

cases, low-fat beef patties have not only taken longer than expected to reach the targeted end-point temperature but also maintained a pink color at temperatures of 160° to 165 °F (Berry, 1994; Troutt et al, 1992).

There is considerable variation both between and within beef patty formulations in endpoint temperature and color even when controlled cooking procedures are followed.

Advice for Consumers

To avoid foodborne illness, USDA recommends that meat and poultry be cooked thoroughly. Thorough cooking is most accurately measured by use of a food thermometer. The thermometer should penetrate the thickest part of the food. For a meat loaf or a casserole, it would be in the center.

Fresh or thawed ground meat should be used quickly, within one day. Consumers should either tightly wrap and freeze, or store ground beef for no more than one day in a 40 °F refrigerator.

The only way to be sure a ground beef patty is cooked to a high enough temperature to destroy any harmful bacteria that may be present is to use an accurate instant-read thermometer.

For ground beef patties, a digital instant-read food thermometer may be used toward the end of the cooking time and inserted at least ½ inch into the thickest part of the patty. If the ground beef patty is not thick enough to check from the top, the thermometer should be inserted sideways. If uncertain about the temperature reading, take a reading in a second location. Ground beef should be cooked to an internal temperature of 160 °F on an instant-read food thermometer.

The color of cooked ground beef can be quite variable. At 160 °F, a safely cooked patty may look brown, pink, or some variation of brown or pink.

When a patty is cooked to 160 °F throughout, it can be safe and juicy, regardless of color.

Eating pink ground beef patties without first verifying that the safe temperature of 160 °F is reached is a significant risk factor for foodborne illness (Kassenborg et al, 1998; Slutsker et al, 1998).

Consumers should not eat ground beef patties that are pink or red in the middle unless a food thermometer is used to verify the temperature.

When eating out, ask your server if ground beef patties have been cooked to at least 155 °F for 15 seconds (as recommended by the U.S. Food and Drug Administration Food Code), which is a safe option for restaurants or food service operations.

Thermometer use to ensure proper cooking temperature is especially important for those who cook or serve ground beef patties to people most at risk for foodborne illness because *E. coli* O157:H7 can lead to serious illness or even death. Those most at risk include young children, the elderly, and those who are immunocompromised.

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