BEEF FACTS
Product Enhancement

Iridescence: A rainbow of colors, causes, and concerns

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Introduction

Meat purchasing decisions are influenced by product appearance more than any other quality factor because consumers interpret color as an indicator of product wholesomeness. While discoloration is commonly associated with the formation of metmyoglobin due to pigment oxidation, iridescence also can negatively impact consumer satisfaction because it is often misinterpreted as indicating the presence of chemical additives and/or microbial spoilage (Wang, 1991). Iridescence is a physical phenomenon that results in shiny, rainbow-like colors seen not only in raw and cooked meat products, but also in peacock feathers, fish scales, and soap bubbles. The most common colors associated with iridescence on the surface of cooked meat products are green, red, orange, and yellow. For a visual of this effect, see Figures 1 and 2.

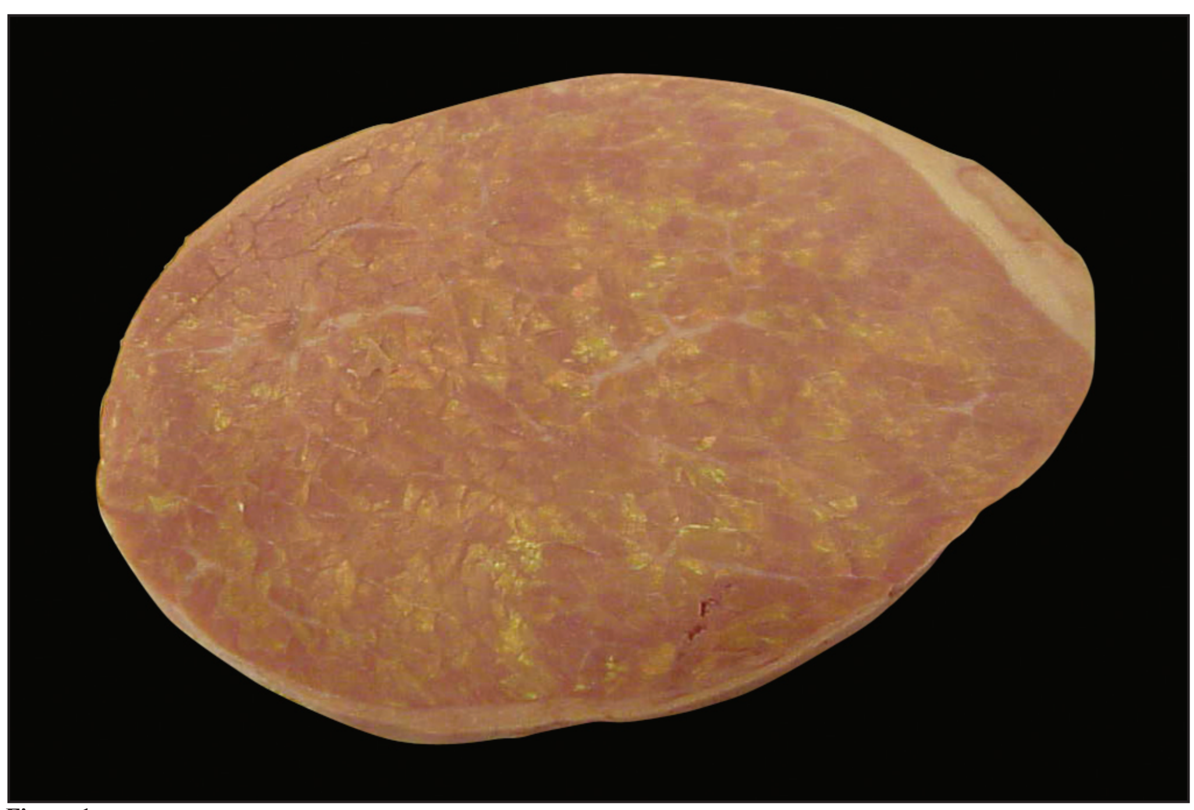

Figure 1 *Pictures courtesy of The Kansas State University Meat Science Program*

Mechanism of iridescence

Food product appearance is based on three factors: a light source, an object that absorbs and reflects light, and an observer. Whereas fresh meat color is typically determined by pigment content and redox state, Swatland (1984) concluded that muscle surface structure had the greatest contribution to iridescence. Therefore, pigments may not contribute to iridescence other than producing background color that can be mixed to result in a kaleidoscope-like appearance. In agreement, Wang (1991) reported that precooked beef semitendinosus bleached with hydrogen peroxide still contained iridescence. This further implies that iridescence is a physical phenomenon not associated with pigment redox state.

The commonly accepted mechanism for iridescence involves optical light diffraction resulting from muscle's striated structure and fibrous nature. In particular, A- and I-band striations combined with light parallel to muscle bundles likely produces iridescence. Wang (1991) further concluded that iridescence is primarily associated with the microstructure of intact meat products as ground products did not produce iridescence.

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Factors affecting iridescence

Muscle type

Several researchers have concluded that iridescence is commonly associated with both raw and cooked semitendinosus muscles (Wang, 1991; Lawrence et al., 2002; Kukowski et al., 2004). In particular, Kukowski et al. (2004) ranked the following beef muscles from most likely to display iridescence to least likely: semitendinosus, semimembranosus, longissimus, gluteus medius, rectus femoris, biceps femoris, and the psoas major.

Two mechanisms responsible for muscle-to-muscle variation in iridescence have been proposed. Lawrence et al. (2002) noted that muscle differences may be associated with fiber orientation during slicing; semitendinosus fibers being more perpendicular to the slicer blade than semimembranosus and biceps femoris fibers. Kukowski et al. (2004) attributed muscle differences to pH. In their research, both the semitendinosus and the psoas major were cut perpendicular to the fibers, yet essentially all psoas major (pH = 5.74) muscles were devoid of iridescence whereas nearly half of semitendinosus (pH = 5.60) muscles displayed moderate iridescence. It is also likely that fiber type (red vs. white), and possibly more important, fiber diameter (small vs. large), may be responsible for muscle-to-muscle variation in iridescence.

Surface structure

Structural uniformity within a muscle promotes light diffraction patterns that are conducive to iridescence (Wang, 1991). Conversely, disruption of surface microstructure limits iridescence. Lawrence et al. (2002) attached sandpaper (120 or 80 grit) to a slicer blade to determine the effects of meat surface roughening during slicing on cooked beef iridescence. Surface roughening resulting from sandpaper addition decreased iridescence compared with a conventional slicer blade. This observation was attributed to the shearing mechanism of sharp blades, which results in a smooth surface that allows both increased light penetration beneath the surface and greater interference of reflected light. Dull blades cause light to be reflected in a more irregular pattern due to meat product surface roughening. Other research noted that blade tenderization minimized iridescence in cooked beef semitendinosus (Obuz et al., 2002).

Sample, lighting, observation, and cutting angle

Iridescence is difficult to quantify because its intensity is significantly affected by sample, lighting, and observation angle (Wang, 1991). For example, intensity of iridescence increased as both lighting and observation angle decreased (Wang 1991). This is further complicated by cutting angle, which significantly affects iridescence as semitendinosus muscle cut longitudinally to fiber orientation does not produce iridescence. Interestingly, iridescence did not appear until the cutting angle became more perpendicular to the muscle fibers and approached 45°, after which iridescence increased as cutting angle increased (closer to perpendicular).

Figure 2 *Pictures courtesy of The Kansas State University Meat Science Program*

Hydration state

The sporadic occurrence of iridescence has been attributed to the hydration state of meat and interfilament spacing (Swatland, 1988). This was partially confirmed by Wang (1991), who suggested that air exposure, moisture evaporation, and dehydration reduced iridescence whereas water addition to a semi-dried surface caused iridescence to reappear. Therefore, of the three forms of water in meat, free water may be most related to the production of iridescence. Wang (1991) also reported that increasing the amount of injected water from 3 to 10% increased iridescence on the surface of cooked beef semitendinosus. It is likely that dehydration does not irreversibly alter muscle structure, but rather influences iridescence via changes in myofibril swelling and shrinkage compared with smooth, wet surfaces.

Ingredients and additives

Ockerman (1983) suggested that added salt scatters or disperses light into its constituent spectral colors (rainbow colors) much like a prism. However, Wang (1991) concluded that the prism effect resulting from added salt played a negligible role in iridescence as washing/soaking treatments intended to remove salt from the meat surface did not minimize the occurrence of iridescence. Additionally, iridescence is often noted in raw and unseasoned meat products. Based on similar experiments, Wang (1991) also proposed that iridescence may actually be an immediate subsurface optical phenomenon.

Incorporation of phosphate also may influence iridescence, but not via direct scattering of light as with salt. Rather, phosphate's role in iridescence is likely through the ability of alkaline polyphosphate to alter protein charge by shifting pH away from the isoelectric point (Wang, 1991). Resulting changes in myofibril spacing and water retention would encourage iridescence.

Surface films

Thin film interference, possibly resulting from surface oil smear upon slicing, also has been associated with iridescence (Holland, 1980; Ockerman, 1983). However, Wang (1991) reported that the addition of vegetable oil to the cut surface of cooked beef did not increase iridescence. Interestingly, unlike water addition to semi-dry meat surfaces, adding vegetable oil after exposure of the meat to air did not regenerate iridescence.

Conclusions

Iridescence is a physical phenomenon resulting in a rainbow-like appearance that can be misinterpreted by consumers as product unwholesomeness. Of the spectrum of colors produced by surface iridescence, green, red, and orange are most common.

Iridescence is difficult to quantify as its intensity is significantly affected by sample, lighting, and observation angle. This creates a major obstacle to researchers interested in measuring or determining factors affecting iridescence.

The mechanism of iridescence is primarily associated with product surface microstructure and light diffraction. Smooth and wet surfaces tend to reflect light in a manner that is more conducive to iridescence whereas rough and dry surfaces tend to limit iridescence.

The *semitendinosus*, both raw and cooked, is frequently prone to iridescence. This has been attributed to fiber orientation, which is often more perpendicular to slicing blades when compared with other beef muscles. Nevertheless, muscle fiber type and diameter also may play a role in iridescence.

Further research is needed to determine the exact mechanism of iridescence as well as assess processing factors that can prevent its occurrence.

Other factors evaluated

<u>Connective tissue:</u> Swatland (1984) concluded that intramuscular connective tissue played a negligible role in iridescence on the surface of cured beef biceps femoris. Rather, production of iridescence was attributed to myofiber transverse sections.

<u>Freezing:</u> While iridescence was minimized by freezing, likely due to ice crystal-induced alterations in microstructure, it reappeared upon thawing (Wang, 1991).

<u>Cooking:</u> Increasing endpoint temperature from 54.4° to 60°C increased beef semitendinosus iridescence (Wang, 1991). This was attributed to structural changes resulting from protein coagulation and shrinkage. Faster cooking also resulted in more semitendinosus iridescence (Kukowski et al., 2004).

<u>Tenderness:</u> In cooked beef semitendinosus, shear force was not correlated to iridescence (Wang, 1991). Similarly, Kukowski et al. (2004) also concluded that tenderness was not significantly correlated with semitendinosus iridescence ($r = 0.06$).

<u>Carcass traits:</u> Kukowski et al. (2004) reported that neither skeletal maturity, marbling, hot carcass weight, fat thickness, nor yield grade were significantly correlated with semitendinosus iridescence. Conversely, lean maturity and ribeye area were moderately correlated ($r = -0.5$ and 0.30, respectively) with iridescence. In raw beef semitendinosus, fat content was negatively correlated with iridescence (Wang, 1991). This suggests that leaner meat may be more susceptible to iridescence. Dark cutting carcasses were less likely to display iridescence than carcasses with normal ultimate muscle pH ($P = 0.02$). No difference in semitendinosus iridescence was noted between steers and heifers (Kukowski et al., 2004).

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