Can Information and Climate Smart Labeling Reduce Food Waste from Discolored Beef?

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1. Introduction and Literature Review

Food waste is a pressing global issue with significant environmental, economic, and social consequences. According to the Food and Agriculture Organization (FAO), approximately one-third of all food produced globally, roughly 1.3 billion tons, is wasted each year (FAO, 2013). Food waste can occur throughout the supply chain, from production and distribution to retail and consumer levels, a large proportion arising from the rejection of food due to cosmetic imperfections despite being perfectly edible with the same nutritional value and flavor as more visually appealing products (de Hooge et al., 2017; White et al., 2016). Deviations in size, shape, color, and surface quality, such as misshapen carrots, oversized apples, yellowed cauliflower heads from sunlight exposure, or blemishes and scratches from handling, frequently result in produce being discarded. These imperfections often fail to meet retailer and consumer standards. As a result, farmers may leave such items unharvested, retailers might reject or discard them, and consumers may bypass them at the store (Bratanova et al., 2015; Loebnitz and Grunert, 2015).

A substantial body of literature has examined consumer preferences for cosmetically or visually imperfect food products, with particular emphasis on fruits and vegetables such as stone fruits, kale, sweet potatoes, and carrots (Bolos et al., 2021; Hingston & Noseworthy, 2020; Behler et al., 2024; Collart et al., 2019; Qi et al., 2022). These studies consistently find that consumers tend to avoid purchasing visually imperfect products. Certain types of imperfections may signal reduced quality, nutrition, and taste to consumers (White et al., 2016). For example, holes in leafy greens may be perceived as signs of pest damage or disease; discoloration in fruits may be interpreted as a sign of immaturity; bruising may suggest spoilage or lack of freshness; damaged packaging can raise concerns about contamination; and misshapen fruits and vegetables may evoke negative aesthetic or emotional responses.

In parallel, another stream of research has investigated strategies to promote the acceptance and purchase of these visually imperfect products. While price discounts remain a common practice (Aschemann-Witzel et al., 2018), scholars have also explored alternative interventions, including marketing message framing (Grewal et al., 2019; Shao et al., 2020) and the promotion of environmental sustainability benefits (Makhal et al., 2020; Xu et al., 2021). For instance, Van Giesen and De Hooge (2019) demonstrated that positioning these products with sustainability- or authenticity-based messaging can enhance consumers' purchase intentions and perceptions of product quality. Moreover, explicitly labeling these products as being imperfect or ugly has been shown to mitigate negative biases regarding sensory attributes, particularly taste, thus increasing purchase likelihood (Mookerjee et al., 2021). Notably, the effectiveness of these strategies is further improved when combined with a moderate price discount.

There are four main gaps in the existing literature. First, research on visually imperfect meat products is notably limited. Only a few studies have explored consumer preferences for beef steaks and ground beef with varying levels of discoloration. Discoloration where beef turns brown or gray instead of its typical red or pink hue, is caused by the oxidation of myoglobin due to oxygen exposure (Suman and Joseph, 2013). Although this change does not affect meat safety or nutritional quality when properly stored within its quality assurance date, it negatively impacts consumer perception (Mancini et al., 2024). For example, Grebitus et al. (2013) found that consumers strongly preferred bright cherry-red ground beef and were willing to pay $2.00/lb more than for brownish-red beef. Similarly, Feuz et al. (2020) showed that slightly discolored beef often requires at least a 50% discount before consumers consider purchasing it.

Second, it is unclear whether consumer preferences for steak discoloration differ by cut, such as sirloin, New York strip, and ribeye, since tolerance likely varies with expectations for each cut's characteristics (Grunert and Bredahl, 2004). Ribeye, as a premium and costly cut, demands a bright, fresh color, leading consumers to be least tolerant of discoloration. In contrast, sirloin, which is more affordable and often used in dishes where appearance is less critical, generally sees higher consumer acceptance despite some discoloration. The New York strip falls between these two. Third, while promotional strategies have effectively marketed imperfect fruits and vegetables, no one has tested whether information provision on food waste reduction and environmental benefits can similarly influence consumer acceptance of discolored beef. Fourth, labeling such as "ugly" has proven effective in promoting imperfect products (Mookerjee et al., 2021). However, the potential of climate-smart labeling, which highlights beef production practices that reduce carbon emissions, has not been explored in the context of marketing discolored beef. Such environmentally focused labels could potentially increase consumer awareness and acceptance by linking product imperfections to sustainability benefits.

To address these gaps, this study uses a discrete choice experiment (DCE) to investigate consumer preferences and the effectiveness of information provision for discolored beef across different steak cuts, and tests whether climate-smart labeling can interact with the consumer's preference. Approximately 2.55% of beef is discarded due to discoloration, leading to an estimated annual loss of $3.73 billion for the U.S. beef industry (Ramanathan et al., 2022). Given beef's prominence in American diets, understanding consumer preferences toward discolored beef presents a critical opportunity to reduce food waste and promote more sustainable consumption.

2. Experiment Design

Our study relies on a discrete choice experiment (DCE), targeting 2,000 general US consumers. The survey was refined through three rounds of focus groups and one round of pilot testing. It is currently being distributed online via Dynata, with data collection beginning in June 2025 and still ongoing. The survey begins with screening questions to ensure participants are at least 18 years old and responsible for at least 50% of their household's grocery shopping, so that responses reflect household-level preferences. Qualified respondents then answer questions about their attitudes toward discolored beef, grocery shopping habits, and dining-out frequency.

Respondents subsequently proceed to the DCE component of the study. To examine the consumer preferences for discolored steaks across different cuts and information provision strategies, we implement a split-sample design with two layers of randomization. First, respondents are randomly assigned to evaluate one of three steak types: Sirloin, New York Strip, or Ribeye. Within each steak cut group, respondents are further randomized into one of two subgroups: an information treatment or a control group. Other than variation in steak type and the inclusion of information provision, all other survey elements remain uniform across experimental conditions.

Within each treatment group, respondents first view a brief instructional video (approximately 90 seconds in length) that introduces the DCE format and provides guidance on how to select their preferred options. Upon completion of the video, respondents answer three comprehension check questions designed to assess their understanding of the key information. If any question is answered incorrectly, a clarification message is displayed to reinforce accurate interpretation.

Respondents assigned to the information treatment condition are then presented with an informational script that explains the primary cause of beef discoloration (exposure to oxygen), reassures them of its safety for consumption and highlights its potential benefits in reducing food waste and promoting environmental sustainability. Following this, all respondents are shown a brief "cheap talk" script, which acknowledges the tendency for individuals to overstate preferences or agreement in survey compared to real-world purchasing. The script encourages participants to approach the upcoming choice tasks as if they were making actual purchase decisions, despite the hypothetical nature of the survey.

All respondents subsequently complete the choice tasks. The experimental design was developed using Ngene software to achieve D-efficiency and comprises 24 unique choice sets, which are divided into four blocks. Each respondent is randomly assigned to one block and completes six choice sets. A sample choice set is presented in Figure 1. Each set includes three steak alternatives and an opt-out option, the latter designed to reflect real-world purchasing scenarios where consumers may choose not to purchase any of the available options. The steak cut corresponds to the respondent's assigned treatment group. Each steak alternative is described using four attributes: (1) level of discoloration (none, light, moderate), (2) remaining shelf life (1, 3, or 5 days before the "best if used by" date), (3) climate-smart labeling (none, 15%, or 30% carbon reduction through climate-smart farming practices), and (4) price (levels vary by steak cut). A summary of attribute definitions and levels is provided in Table 1. Following the choice tasks, respondents complete a set of demographic questions such as age, gender, and educational attainment to conduct analyses of preference heterogeneity.

3. Econometric Strategy

To analyze consumers' preference over discolored beef, we apply a conditional logit model and two mixed logit models (with or without full correlation between random parameters). The set-up of each model is discussed as follows, respectively. Following the random utility model (RUM) (McFadden, 1974), respondent n will get utility U_{njt} from choosing alternative j characterized by a set of attributes x_{njt} in choice set t:

$$U_{njt} = \beta' x_{njt} + \varepsilon_{njt} \tag{1}$$

where β is a set of corresponding preference parameters for all attributes, and ε_{njt} is a random term that represents the unobserved component of utility. We assume that the random terms are independent and identically distributed (IID), and the conditional logit probability of a respondent n choosing alternative j in choice scenario t can be derived as:

$$P_{njt} = \frac{e^{\beta' x_{njt}}}{\sum_{j=1}^{J} e^{\beta' x_{njt}}} \tag{2}$$

As suggested, conditional logit model assumes β remain fixed across all individuals. To better account for preference heterogeneity, this model can be extended to a mixed logit model, which is formulated as follows:

$$U_{njt} = \beta_i' x_{njt} + \varepsilon_{njt} \tag{3}$$

where the parameters β_i for attributes, rather than fixed, are assumed as random variables themselves and may take different values across the sampled respondents. Given the random parameter context, the choice probability becomes:

$$P_{njt} = \int \frac{e^{\beta_i' x_{njt}}}{\sum_{j=1}^{J} e^{\beta_i' x_{njt}}} h(\beta) d\beta \tag{4}$$

where $h(\beta)$ denotes the joint density function of the random parameters β. These random parameters may be correlated or uncorrelated. As proposed by Hess and Train (2017), the mixed logit model that allows for a full covariance matrix among the random parameters represents the most general and flexible specification. This approach accommodates correlations arising from scale heterogeneity as well as other behavioral factors that influence the overall correlation structure among utility coefficients.

After estimating the model, we will calculate the willingness to pay (WTP) as the negative ratio of the coefficient of a non-price attribute to the coefficient of the price attribute.

$$WTP = -\frac{\beta_{non-price}}{\beta_{price}} \tag{5}$$

4. Preliminary Results

As of now, we have collected responses from over 250 participants. After removing incomplete, inattentive, and potentially fraudulent responses, a total of 217 valid responses remain for analysis[1]. These are distributed across the three steak treatment groups as follows: 71 for Sirloin, 75 for New York Strip, and 71 for Ribeye. Within each group, approximately half of the respondents (around 35) received the information treatment. Given the current limited sample size, the summary statistics are not yet representative of the broader U.S. population, and some baseline variables are not fully balanced across treatment groups. As such, the findings presented

[1] We included three attention check questions evenly distributed throughout the survey. Respondents were classified as attentive only if they answered at least two of the three attention checks correctly. To identify and remove potentially fraudulent responses, we relied on the Qualtrics-generated variable "Q_RecaptchaScore." Responses with a score below 0.5 or missing values were considered likely to be generated by bots and were excluded from the final dataset.

should be considered preliminary. Final results may evolve as data collection continues, with full completion expected after September 2025.

4.1 Model Results

Tables 2 and 3 present the estimation results from the conditional logit and mixed logit models, respectively. For each model type, we estimate separate models for the Sirloin, New York Strip, and Ribeye treatment groups. All models include the main product attributes and their interactions with the information treatment indicator to capture potential differences in preferences between respondents exposed to the information treatment and those in the control group. Given that the mixed logit model accounts for preference heterogeneity by allowing coefficients to vary randomly across individuals, our interpretation primarily focuses on the results reported in Table 3.

Table 3 reveals four key findings. First, for the main effects, as expected, respondents are price-sensitive, as indicated by the significantly negative price coefficients across all four models. This suggests a general preference for lower-priced steaks. The coefficients on the optout option are also significantly negative, indicating that respondents prefer to purchase the reference steaks, which are those without discoloration and without climate-smart labels. Second, the coefficients for climate-smart labels indicating 15% and 30% carbon reduction (CS15 and CS30) are generally positive, suggesting a potential preference for these labels. However, most of these coefficients are not statistically significant. This may suggest that, overall, respondents place limited value on climate-smart production practices in beef, although the lack of statistical significance could also be attributed to the limited sample size.

Third, the coefficients for discoloration (both light and moderate levels) are significantly negative, indicating that respondents strongly dislike discolored beef, with moderate discoloration being less preferred than light discoloration, as reflected by a more negative coefficient for Moderate compared to Light. The coefficients for remaining shelf life (i.e., number of days until expiration) are positive, which aligns with expectations that steaks with more remaining days are perceived as fresher. However, these coefficients are not statistically significant, possibly due to the limited sample size. Last, the interactions of the information treatment group indicator and the with price and optout are significantly negative, while interactions with the other attributes are not significant. These negative interactions suggest that respondents in the information treatment group are more price-sensitive and more likely to choose the baseline steak without discoloration and without climate-smart labels.

4.2 WTP Results

The more negative price coefficients observed in the information treatment group may suggest lower WTP for all attributes, given the role of the price coefficient in the denominator of the WTP calculation (Equation (5)). Table 4 presents the estimated WTP values for all attributes across the three models using both conditional and mixed logit specifications. We compare WTP across treatment groups (with and without the information treatment) and across different steak cuts to assess how information provision influences consumer valuation. Again, given the greater flexibility of the mixed logit model in capturing preference heterogeneity, our interpretation primarily focuses on the WTP estimates derived from the mixed logit models, which are reported in the lower panel of Table 4.

We have three main findings in Table 4. First, for the climate-smart label indicating a 15% reduction in carbon emissions, only respondents in the Ribeye group who received the information treatment exhibit a statistically significant and positive WTP. Specifically, holding all else constant, these respondents are willing to pay an additional $2.823 for Ribeye steaks featuring this carbon-related label. In contrast, no significant price premium is observed for Sirloin or New York Strip steaks. This finding aligns with our expectation that Ribeye, as a premium cut, tends to attract consumers who associate high-end products with environmental values. Additionally, the provision of information may have heightened respondents' environmental awareness, thus increasing their valuation of the climate-smart label. However, this effect does not extend to the 30% carbon reduction label, as none of the corresponding WTP estimates are statistically significant.

Second, for light discoloration, we observe significantly negative WTP estimates across all steak types, indicating a general aversion to discolored meat. Prior to the information treatment, the most negative WTP is observed for New York Strip (–$13.503), followed by Sirloin (–$7.296) and Ribeye (–$5.665). After the information is provided, the ranking shifts: WTP becomes most negative for Ribeye (–$5.694), followed by Sirloin (–$3.429), and New York Strip (–$2.772). Notably, WTP becomes significantly less negative for both Sirloin and New York Strip, suggesting that the information treatment helps mitigate consumer concerns regarding discoloration. In contrast, the WTP for Ribeye becomes slightly more negative after the information, although this change is not statistically significant.

For moderate discoloration, the magnitude and ranking of WTP follow a similar pattern to that of light discoloration, both before and after the information provision. In all cases, the WTP becomes less negative when information is provided, although the difference is statistically significant only for New York Strip. These results are consistent with our expectation that, after receiving information explaining the causes of discoloration and the potential benefits of purchasing discolored beef, respondents exhibit reduced aversion to such products, as reflected in the less negative WTP estimates. While some differences are not statistically significant, this may be attributed to the limited sample size at the current stage of data collection.

Lastly, for the "remaining days" attribute, a statistically significant and positive WTP is observed only for Sirloin when information is provided, with respondents willing to pay $0.459 for each additional day until the expiration date. This positive WTP, however, is not observed for the other steak types, which may again be attributed to the limited sample size and reduced statistical power.

5. Conclusion

This study contributes to the growing literature on consumer preferences for cosmetically imperfect food by focusing on discolored beef which is a visually imperfect yet safe and nutritious product that frequently goes to waste. While previous research has examined consumer responses to imperfect fruits and vegetables, little is known about consumer valuation of discolored meat or how informational and labeling interventions might influence such preferences. Using DCE, we examine consumers' WTP for discolored beef steaks across three popular cuts such as Sirloin, New York Strip, and Ribeye, while also testing the effects of an informational treatment and climate-smart labeling.

Our preliminary findings, based on a sample of 217 U.S. consumers, yield several promising insights. First, as expected, consumers show strong aversion to both light and moderate discoloration, with greater negative WTP for moderate discoloration. However, the provision of information explaining the causes of discoloration and emphasizing the environmental benefits of reducing food waste helps mitigate this aversion, particularly for Sirloin and New York Strip. This suggests that educational messaging can be an effective, low-cost strategy to reduce negative perceptions of discolored meat. Second, while climate-smart labels indicating a 15% or 30% reduction in carbon emissions were not generally valued across all respondents, those in the Ribeye group who received the information treatment exhibited a statistically significant WTP premium for the 15% label. This indicates a potential synergy between premium cuts and sustainability messaging, suggesting that consumers purchasing higher-end cuts may be more responsive to environmentally focused product attributes when adequately informed. Additionally, consumers assign positive value to longer shelf life, although this effect was statistically significant only for Sirloin in our current sample.

Taken together, these findings suggest that targeted information provision can be a scalable and effective intervention to reduce food waste and encourage more sustainable consumption of discolored beef. As data collection continues, future analyses with a larger sample will help validate these initial patterns and allow for deeper investigation into preference heterogeneity, potentially through mixed logit model with fully correlated random variables, latent class analysis or hybrid choice modeling. Furthermore, we plan to explore the interaction effects between climate-smart labels and discoloration levels to assess whether such sustainability labeling can further enhance consumer acceptance of visually imperfect products.

Tables and Figures

Tables

Table 1. Attributes and levels

Attributes	Levels
Discoloration	No discoloration* Light discoloration: *light* Moderate discoloration: *moderate*
Remaining days: before the date of best if used	1 day * 3 days 5 days
Climate smart	No 15% carbon reduction: *CS15* 30% carbon reduction: *CS30*
Price (per pound)	Sirloin: • $4.99; $7.99; $10.99; $13.99 New York Strip: • $8.99, $11.99, $14.99, $17.99 Ribeye: • $14.99, $17.99, $20.99, $23.99

Table 2. Conditional logit model results

Variables	Sirloin	NYStrip	Ribeye
Price	-0.2044***	-0.1261***	-0.1711***
Optout	-2.7296***	-2.4111***	-3.6016***
Cs15	0.1238	0.3035	-0.0043
Cs30	0.1452	0.1703	0.2296
Light	-1.0780***	-1.5346***	-0.9320***
Moderate	-2.8029***	-2.1937***	-2.1361***
Remaind	0.1023*	0.0713	0.0353
Optout_inf	-0.8984	-1.5606	-0.6375
Price_inf	-0.0455	-0.1242**	-0.011
Cs15_inf	-0.3212	-0.219	0.5185
Cs30_inf	-0.1765	-0.0243	0.3184
Light_inf	0.3124	0.8692***	-0.0228
Moderate_inf	0.2753	0.7091*	-0.0554
Remaind_inf	-0.008	0.0495	-0.018
N	71	75	71
LL_0	-590.5614	-623.8325	-590.5614
LL	-434.7159	-494.5979	-484.4159
Chi2	311.691	258.4691	212.291
AIC	897.4318	1017.1958	996.8318

* p<0.10, ** p<0.05, *** p<0.01

Table 3. Mixed logit model results

Variables	Sirloin	NYStrip	Ribeye
Price	-0.2782***	-0.1728***	-0.3057***
Optout	-3.5620***	-3.2483***	-6.8691***
Cs15	0.2703	0.4471	-0.0744
Cs30	0.5957	0.1663	0.5902
Light	-2.0297***	-2.3337***	-1.7321***
Moderate	-6.1442***	-3.8556***	-5.1463***
Remaind	0.1632	0.1445	-0.089
Optout_inf	-1.871	-2.6283*	-1.007
Price_inf	-0.1536*	-0.1885**	-0.0172
Cs15_inf	-0.4359	-0.4332	0.8646*
Cs30_inf	-0.6154	-0.1137	-0.0917
Light_inf	0.5491	1.3320**	-0.1063
Moderate_inf	0.3647	1.4319*	-0.1024
Remaind_inf	0.035	0.027	0.0583
SD			
Cs15	0.0831	-0.3999	0.1464
Cs30	0.0733	1.1762***	-1.3880***
Light	2.2399***	1.4677***	1.8456***
Moderate	3.8186***	2.1662***	3.2830***
Remaind	0.3698***	0.4233***	0.6199***
N	71	75	71
LL_0	-434.7159	-494.5979	-484.4159
LL	-379.7442	-447.1338	-409.6832
Chi2	109.9433	94.9283	149.4655
AIC	797.4885	932.2676	857.3663

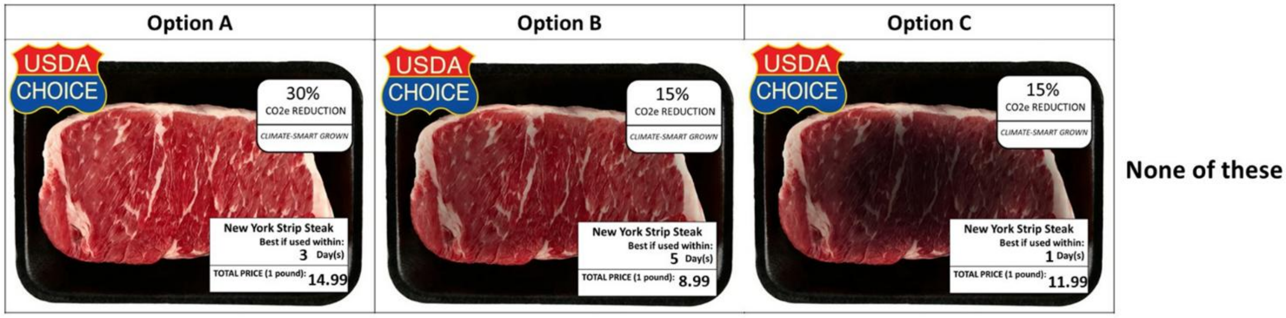
* $p<0.10$, ** $p<0.05$, *** $p<0.01$

Table 4. WTP estimates

Variables	Sirloin		WTP diff		NYStrip		WTP diff		Ribeye		WTP diff	
Conditional logit												
CS15	0.606		-1.396		2.407		-2.070		-0.025		2.848	*
CS15_infor	-0.790				0.337				2.823	*		
CS30	0.710		-0.836		1.351		-0.768		1.342		1.667	*
CS30_infor	-0.125				0.584				3.009	*		
Light	-5.275	***	2.210	*	-12.174	***	9.515	***	-5.446	***	0.203	
Light_infor	-3.064	***			-2.658	***			-5.243	***		
Moderate	-13.714	***	3.598		-17.402	***	11.471	**	-12.482	***	0.448	
Moderate_infor	-10.116	***			-5.931	***			-12.034	***		
Remaind	0.500		-0.123		0.566		-0.083		0.206		-0.111	
Remaind_Infor	0.377				0.483	**			0.095			
Mixed logit												
Variables	Sirloin		WTP diff		NYStrip		WTP diff		Ribeye		WTP diff	
CS15	0.972		-1.355		2.587		-2.548		-0.243		2.691	*
CS15_infor	-0.383				0.039				2.447	**		
CS30	2.141		-2.187		0.963		-0.817		1.931		-0.387	
CS30_infor	-0.046				0.146				1.544			
Light	-7.296	***	3.867	*	-13.503	***	10.731	***	-5.665	***	-0.028	
Light_infor	-3.429	***			-2.772	***			-5.694	***		
Moderate	-22.086	***	8.702		-22.31	***	15.602	**	-16.833	***	0.577	
Moderate_infor	-13.385	***			-6.708	***			-16.256	***		
Remaind	0.587		-0.128		0.836		-0.362		-0.291		0.196	
Remaind_Infor	0.459	*			0.475				-0.095			

* p<0.10, ** p<0.05, *** p<0.01

Figures



Which New York Strip steak would you like to buy?

- ◯ Option A
- ◯ Option B
- ◯ Option C
- ◯ I don't want to buy any of these three options.

Figure 1. Sample choice set for New York strip

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