Consumer preferences for beef based on color

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PRELIMINARY DRAFT – DO NOT QUOTE

Retailers often discount or discard beef that changes from a cherry red color to a brown hue, despite its potential microbiological safety for consumption in the majority of cases. This practice contributes to significant meat waste within the U.S. retail sector. In order to understand consumer demand behavior with regard to beef color and derive measures to successfully market discolored beef and reduce food waste, this study investigates the color preferences of U.S. beef consumers. It uses a hypothetical discrete choice experiment based on digital photos of beef steaks with different color, price, and discount labels in retail packaging. Results of a Mixed Logit Model show that beef shoppers prefer color nearly linearly across days of retail display with a decreasing willingness to pay for all days of retail display relative to day zero. Results of this research provide a more detailed understanding of consumer meat purchasing decisions that need to be incorporated into future demand estimation and global economic modeling.

Keywords: meat color, consumer preferences, choice modeling, food waste, demand estimations

1. Introduction

Reducing food waste is crucial for creating sustainable food systems, given increased global food demand in the context of resource constraints and planetary boundaries (Searchinger et al. 2018; Springmann et al. 2018). Approximately one-third of global food production is lost or wasted annually, causing economic losses of US$1 trillion a year as well as additional environmental costs of about US$700 billion at a global level (FAO 2014). Among food items that are wasted, meat is an important component as it is highly perishable and primarily associated with the environmental impact of food waste (Lipinski 2020; FAO 2014). The issue of meat waste at retail due to consumer preferences has recently gained attention in sustainability discussions. Beef turning brownish red to brown is typically discounted or even discarded by retailers although it could be microbiologically safe for consumption in most cases (Ramanathan et al. 2022).

In order to understand consumer preferences for color and derive measures to successfully market discolored beef and reduce food waste, the objective of this study is to investigate the purchasing behavior of U.S. beef consumers. Consumers attitudes, preferences, willingness to pay (WTP), and the effects of discounts were examined with a hypothetical discreet choice experiment conducted using digital photos of steaks with different color, price, and discount label in retail packaging. A Mixed Logit Model (MLM) was applied to analyze the choice data.

The assessment of U.S. consumer beef color preferences based on quantitative color measurements will support retailer marketing, potentially reshaping long-term consumer perceptions and preferences and thereby combating meat waste and its associated resources. Moreover, the outcome of this research can potentially contribute to accurately modeling meat demand trends and assess corresponding effects on global meat markets in the context of targeted marketing and policy measures that aim to bring about more sustainable meat demand behavior.

2. Materials and Methods

2.1 Survey design

Between June and August 2023, a consumer survey on beef purchasing behavior was conducted utilizing Qualtrics software (XM, Seattle, WA, USA) on iPads, specifically the 10th generation models. Prior to the main survey, the comprehensibility of the questionnaire was validated through a pre-test with multiple people in the Departments of Animal Sciences and Agricultural and Resource Economics, Colorado State University. Survey participants (n = 389) were recruited at supermarkets or other food purchase facilities in different neighborhoods throughout Fort Collins and Laporte, Colorado.

The survey included three sections covering color perception, the self-declared beef purchasing behavior of participants and a hypothetical discreet choice experiment. The questionnaire also collected sociodemographic information. The discreet choice experiment (DCE) was performed in order to determine consumer preferences regarding discolored beef steaks in retail packaging. Based on digital photos of packaged beef steaks, three product attributes: 1) beef color, 2) price, and 3) discount sticker and their respective levels were included in the DCE as presented in **Table 1**.

Table 1. Attributes and levels considered in the discreat choice experiment

Attribute	**Level**
Beef steak color	Color at day 0 of retail display
	Color at day 4 of retail display
	Color at day 7 of retail display
	Color day at 9 of retail display
Price (per lb. beef steak)	$12.99
	$14.99
	$16.99
	$18.99
Discount sticker (total savings per steak)	30% off price per lb.
	No discount

The steaks were cut from USDA Choice beef striploins (IMPS 180; i.e., *longissimus lumborum*) and placed in white foam trays with absorbent pads, overwrapped with polyvinyl chloride (PVC) film. They were stored in a retail case (3°C) under constant fluorescent light exposure for 14 days, whereby discoloration was documented using a digital single-lens reflex (SLR) camera (Nikon D90) and a HunterLab MiniScan LabScan EZ4500 colorimeter for color measurements; digital photos taken as well as *L*, a* and b** values measured during retail display are presented in **Table 2**.

Table 2. Beef steak color and photes selected for inclusion in the Discrete Choice Experiment

Day of retail display	Images	*L**	*a**	*b**
0		**HunterLab** 36	22	23
4		**HunterLab** 34	19	19
7		**HunterLab** 33	17	18
9		**HunterLab** 34	14	16

A D-optimal design was created using Ngene (Choicemetrics, Version 1.1), resulting in 12 choice sets with two product alternatives each and one opt-out option ("I choose neither of these alternatives") which varied randomly for each respondent. Respondents were placed in a theoretical shopping situation using a standard cheap talk script and asked to consider their actual budget when making purchasing or non-purchasing decisions.

2.2 Model specification and data analysis

In total 297 participants' responses were analyzed. Based on an ishihara color test, five participants (1.59%) were excluded from the sample prior to analyzing the choice data, thirteen participants (4.13%) chose to not to purchase any beef steak across all 12 choice scenarios and were excluded from subsequent analysis.

Discrete choice modeling is based on utility theory and assumes that the overall benefit (utility) of a product is a sum of that product's attributes. In a discrete choice experiment, participants choose the product returning their highest utility at the lowest cost, which is why utility maximization of product attributes can be assumed to explain consumer behavior (McFadden 1986).

The Mixed Logit Model (MLM) accounts for repeated choices and enables preferences to vary randomly and independently amongst consumers (Revelt and Train 1998). Based on known attributes, the model assumes a portion of the utility to be deterministic, the remainder is random. The deterministic portion is assumed to be linear so that individual *i*'s marginal utilities of observable attributes associated with alternative *j* can be summed:

$$U_{ijt} = ASC + \alpha Price_{ijt} + \beta_i X_{ijt} + z_i \delta_j + \varepsilon_{ijt}$$

where ASC is the alternative specific constant (opt-out option); α is fixed marginal utility of price, $Price_{ijt}$ given the price of alternative *j* for individual *i* in scenario *t*. β_i are random utility coefficients *Xijt*, a k-dimensional vector of observed non-monetary product attributes (i.e., color,

price discount) and their respective levels for alternative *j*, individual *i* and choice scenario *t*. δ_j are fixed alternative-specific coefficients for case-specific variables (z_i). ε_{ijt} is an i.i.d. error term that follows a type I extreme value distribution.

Consumer's color, price and discount preferences were modelled using a mixed logit model (MLM), whereby 0 days of retail display and no discount sticker were used as reference levels to determine the marginal utility and WTP. Willingness to pay in preference space for the beef color was calculated according to Hensher, Rose, and Greene, W. H. (2015):

$$WTP = \frac{\beta_{attribute}}{\beta_{price}}$$

with 1000 Krinsky repetitions to calculate confidence intervals.

3 Results

Statistically significant ($P < 0.05$) results of the MLM based on choice data are presented in **Table 3**. Preference heterogeneity within the total sample is demonstrated by statistically significant ($P < 0.05$) standard deviations of the random attributes (4, 7, and 9 days of retail display, and price discount). Positive and significant ($P < 0.001$) constant coefficients for choices 1 through 2 (per choice set) show that beef consumers in this survey would "purchase" one out of the two product alternatives instead of choosing "I would not purchase any of those steaks". Negative and significant coefficients for 4,7, and 9 days of retail display in demonstrate that participants see and prefer color nearly linearly across days. Given that the coefficients were negative, color level 0 generates the highest preference among consumers, followed by levels 4 and 7. A steak that with 9 days of retail display was the least preferred by beef consumers.

Table 3. Mixed Logit Model estimates of coefficient means and standard deviations (SD) for the total sample (n = 297).

Variable	Total participants (n=297)		
	Coefficient	Standard error (SE)	p-value
Listed price	-0.13	0.01	***
4 days of retail display	-0.67	0.09	***
7 days of retail display	-1.31	0.11	***
9 days of retail display	-2.65	0.16	***
Discount sticker	0.88	0.10	***
SD			
4 days of retail display	0.73	0.11	***
7 days of retail display	0.99	0.11	***
9 days of retail display	1.80	0.17	***
Discount sticker	1.33	0.09	***
Constant alt1	4.51	0.25	***
Constant alt2	4.38	0.25	***
Log likelihood	-1277.48		

Significances levels: *** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$

On average, consumers demonstrated a negative WTP for all days of retail display, with their preference decreasing nearly proportionately with an increase in discoloration **(Table 4)**. For a steak that was in retail display for 4 days, respondents were willing to pay $5.09 per lb less compared to a steak with 0 days of retail display and discoloration. The WTP was the lowest for 9 days of retail display, respondents will spend $20 per lb less compared to 0 days of retail display. As the average price for the steaks presented was $15.99 per lb, respondents would expect financial compensation for selecting a steak that has experienced 9 days of discoloration.

Table 4. Willingness to pay (WTP) for different days of retail display based on Mixed Logit Model estimates (n = 297)

Variable	**Total sample n=297**		
	WTP	Lower bound	Upper bound
4 days of retail display	-5.08	-6.65	-3.52
7 days of color display	-9.89	-12.21	-7.58
9 days of retail display	-20.05	-24.74	-15.28

Note: Zero days of retail display were used as reference levels to determine WTP.

4 Discussion and Conclusion

It is widely acknowledged that consumers often associate beef color with freshness and wholesomeness when making purchasing decisions (Mancini and Hunt 2005). However, there are only limited studies examining consumer preferences and acceptance of different beef color levels based on quantitative color measurements (Altmann, Trinks, and Mörlein 2023).

Greene, B., Hsin, and Zipser (1971) showed that U.S. consumers reject fresh beef with brown discoloration of over 40%. Similarly, Carpenter, Cornforth, and Whittier (2001) reported a link between beef color preferences and likelihood to purchase, but not between color preferences and eating satisfaction. Killinger et al. (2004) confirmed a preference for bright, cherry red-colored beef of U.S. consumers.

Results of the DCE in this study showed that consumers note clear differences in beef color and prefer color nearly linearly across days of retail display. A bright, cherry red beef steak on day 0 was most preferred, followed by 4, 7 and 9 days of retail display. Accordingly, WTP of consumers decreased with increasing days of retail display and an increasing level of discoloration. In fact, consumers might require financial compensation to contemplate buying a steak that has been on display for nine days and exhibits obvious signs of discoloration.

Similarly, to this study, Grebitus et al. (2013) conducted a choice experiment focusing on various ground beef attributes modifiable through packaging. According to their results, participants favor a light and cherry red color compared to a brownish red color and are willing to pay a premium for ground beef with a cherry red hue.

Holman et al. (2017) provided a comprehensive analysis of beef color preferences by employing a web-based survey using digital photographs of beef steaks (*M. longissimus lumborum*) with pre-established colorimetric values and exploring international beef color acceptability on a six-level interval scale. The authors concluded that consumers consider beef color to be acceptable, with *a**

value being equal to or above 14.5. Results of our study indicate that beef steaks in retail display for up to 7 could still be marketable with a price discount **(Table 4)**. Color measurements for 7 days of retail display showed an *a** value of 17 **(Table 2).** Consumers sought compensation to consider buying a steak that had been discoloring for 9 days **(Table 4)** with an *a** value of 14 **(Table 2)**, indicating a pronounced color sensitivity observed among the participants in this study.

Assessing U.S. consumer color preferences based on quantitative color measurements revealed a nearly linear preference trend for beef color across days of retail display. Beef retailers should consider that beef steaks displayed for nine days are hardly marketable, even with significant price discounts. The outcomes of this research can inform retailer marketing strategies, potentially reshaping long-term consumer perceptions. Research findings can also provide a basis for future demand estimation and modeling in global economic frameworks considering consumer purchasing decisions.

Results of the choice experiment conducted in this study provide a more detailed understanding of consumer meat purchasing decisions that can inform future demand estimation and modeling in global economic frameworks to address research questions related to food waste reduction. Detailed demand behavior and a comprehensive consideration of the food waste problem warrants further investigation. Bartelings and Philippidis (2024) recently introduced a novel macroeconomic modelling assessment of food loss and waste in the EU using a novel characterization of food loss and waste behavior in the MAGNET (Modular Applied General Equilibrium Tool) model. The authors conceptualized food loss and waste generation as a domestic margin commodity, implying that whenever food commodities are consumed or used as inputs, a corresponding waste margin is generated. Adjustments in consumption patterns concerning meat demand, especially in light of food waste could benefit from more nuanced analyses of consumer preferences, exemplified by DCE as demonstrated in this study. However, a basic prerequisite in this context is detailed product level analysis, specified by individual product characteristics. While CGE models typically consider

highly aggregated product categories, product specific models, such as the GTAP-HS model that account for disaggregated product can benefit from greater understanding of consumer preferences for meat and other food.

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