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The Role of Visual Attention and Quality Cues in Consumer Purchase Decisions for Fresh and Cooked Beef: An Eye-Tracking Study

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Abstract

This study analyzes Brazilian consumer behavior regarding quality and visual cues in fresh red meat and cooked beef. Using eye tracking to collect visual attention metrics and psychological scales to assess food behavior, the research examines how visual attention to beef attributes impacts product choice. A discrete choice method combined nine hypothetical products with varied attributes. Results showed that consumers display different visual behaviors toward cues, influencing their probability of choosing a product. For fresh beef, color was the most significant factor, especially bright red and brown hues. Color influenced both the time to first fixation and total fixation time, while breed also affected total fixation time. Dark-red color and unspecified breed information increased the purchase probability, while Nellore breed and brown color decreased it. Total fixation numbers were significantly impacted by color, breed, marbling, and price. In cooked beef, tenderness, price, and flavor were key visual cues. Tenderness and flavor influenced the time to first fixation, whereas price and flavor impacted the number of fixations. This research contributes to understanding visual cues and attention in food choices, suggesting strategies for enhancing beef labeling and communication to better inform Brazilian consumers.

Keywords: eye tracking; visual attention; visual cues; meat; consumer behavior

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1. Introduction

Eye tracking is a powerful and precise method for analyzing visual attention, particularly effective in capturing non-conscious cognitive processes. Traditionally used by psychologists to investigate fundamental mental functions, this technique has gained recognition in other fields such as education and consumer behavior research due to its capacity to track real-time cognitive actions without relying on self-reported data [1].

In consumer research, eye tracking offers an objective means to assess how visual stimuli influence purchasing behavior. By recording participants' eye movements, rather than asking direct questions, researchers can closely simulate real-world shopping scenarios. This allows for the identification of visual elements—such as color, texture, and packaging—that drive consumer decisions at the point of purchase [2].

Beef products provide a compelling case for studying the role of visual attention, as consumers often rely on visual cues to assess quality. For fresh beef, color is the primary indicator, while packaging plays a similar role for cooked beef. Appearance is not only the first sensory attribute to be noticed but is also a key driver of appetite and product acceptability [3]. Prior research has shown that visual features significantly influence expectations related to tenderness, flavor, and overall eating quality—even before tasting the product [4,5].

Despite these insights, consumers often face challenges in accurately predicting beef quality based on visual inspection alone, creating a major challenge for the meat industry. Understanding how consumers interpret visual cues—especially in the context of both raw and cooked forms of the same product—is essential for aligning marketing strategies and product development with consumer expectations.

The existing literature confirms the relevance of visual attention in food choice [6,7], yet few studies have specifically focused on Brazilian consumers. Recent findings indicate that Brazilian consumers associate bright red coloration in fresh beef with higher quality, while a tough texture in cooked beef negatively affects choice and willingness to pay [8].

Therefore, this study has two main objectives: (1) to evaluate how visual attention to different visual and quality cues affects the probability of purchase for both fresh and cooked beef among Brazilian consumers; and (2) to introduce a novel statistical approach to analyze eye tracking data in the context of food choice.

By incorporating both raw and prepared forms of beef, this research captures a more complete understanding of how visual cues shape consumer decision-making throughout the purchasing and consumption cycle.

2. Literature Review

2.1. Visual Attention for Food

Vision is the most used sense during the process of buying food [9,10] because consumers need to visualize information before they can use it in the selection process [11]. Visual attention broadly represents the cognitive process of understanding specific visual information and demarcating these into areas of interest (AOI) [12–15]. Visual attention is understood to be the first stage of a series of processes that influence consumer choice [16].

The attention given by consumers to a stimulus is selective and can be presented in the following two ways: bottom-up, in which attention is directed to stimuli, and top-down, which is related to the objectives of the observer [17,18]. The bottom-up situation occurs when a stimulus stands out in the visual field, that is, attention is guided by visual characteristics, such as the size, color, and shape of a stimulus or internal characteristics of stimuli that automatically capture the attention of individuals [19–22]. Researchers have explored how the appearance of cereal bars influences the consumer purchasing decisions across different brands and flavors [13]. They found that brand and variety were key determinants in driving consumer attention, suggesting that greater attention given to a brand increases the likelihood of its selection. Another study evaluated the effect of visual attention on product labels on chocolates, yoghurt, and tomato with the organic symbol in different sizes [23]. They found that the use of bottom-up effects to improve the design and visibility of this information increased attention capture as well as the probability of product choice.

Conversely, top-down attention occurs when consumers focus on stimuli that are in line with their goals, expectations, and even their emotions [19,24–26]. Research has observed that consumers perceive the healthiness of mayonnaise, bread, and yoghurt, as well as their willingness to buy, and found that consumers directed visual attention to specific information such as ingredients and nutritional information [27]. The effect of

beef fat content on visual attention and purchase choice has also been examined, with researchers finding that consumers pay more attention and more often choose beef with a lower fat content due to the perception of healthiness [28]. Specific objectives can focus on visual attention and food choice [29].

When observing a stimulus, the consumer's eye movements can be measured with eye-tracking equipment, which allows accurate recording of periods and fixation sites. The literature suggests that consumers process AOI information with fixations on specific attributes. Alternations between these fixations, e.g., color and size, are called saccades. Fixations are the periods of attention given to an area of interest, characterized by periods of discrete immobility of the eye while the information is visualized and processed before looking for another AOI. Although it is understood that the view is suppressed during the saccades, they are useful to reveal elements of the consumer's visual search, such as trade-offs and the order seen in the AOI [18,30,31]. In the present study, the AOIs contemplate information on quality and visual cues based on the color, marbling, breed, flavor, tenderness, and aroma of beef.

The main parameters of visual attention contemplated in the present study include the following: (1) time of the first fixation—reflects the time it takes the consumer to process information of an AOI for the first time. In general, information that is more complex for the consumer takes longer to be visualized, so the shorter the time for the first fixation, the greater the ability of information to capture visual attention. (2) The total fixation time—indicates the total time of fixing on an AOI throughout the stimulus. Long fixations may indicate that the consumer has difficulty in interpreting the information presented. (3) The number of fixations in an AOI (number of looks)—refers to the total number of fixations on a specific attribute or area of interest. The more a consumer fixes on an attribute of interest, the more importance the consumer places on this, e.g., color [1,32,33].

The information contained in the food itself is an important communication channel that directs how visual attention and consumer choices will be affected [10,16]. It is important to understand which elements can effectively capture the consumer's attention to explore their behavior and increase the probability of choosing a food [9,13,27]. Thus, eye tracking is used to measure which stimulus information has the shortest time for the first fixation, the path taken by the eye, total fixation time, the percentage of areas fixated on, and the quantity of fixations [16,18,34,35].

Studies focusing on the visual attention of Brazilian consumers have previously been conducted [16,36,37]; however, they focused on other products than beef. As such, the current study aims to contribute novel data that can assist private and government institutions to explore which quality and visual cues are more responsible for the visual attention of consumers. Using this information, it is possible to design strategies to increase the probability of choice and gain insights for future research.

2.2. Quality and Visual Cues for Foods

The quality of a product may have an impact on the food choice process, but only if it is perceived [38]. The visualization of quality cues is necessary for understanding and used at the time of choosing a food product since the first sensory contact of the consumer with food is through the eyes [39]. Thus, before food is effectively chosen by the consumer, visual attention is directed to visual cues, which provide information about the characteristics of food through words, images, symbols, or the appearance of the product [39,40].

Consumers make purchasing decisions based on intrinsic and extrinsic visual cues that they correlate to specific attributes based on prior experience and credibility [41]. Intrinsic visual cues are inherent to the food itself and cannot be manipulated without affecting its physical properties—these include appearance, taste, and texture. Extrinsic visual cues

are related to the product and include labelling, packaging, marketing information or situational contexts [42]. Regarding beef, the main intrinsic visual cues reported are cut, color, fat content, flavor, tenderness, and taste [41–48]. Extrinsic visual cues represent all the other product characteristics, such as brand, price, packaging, origin, and information regarding animal production [5,43,49].

Exposure to visual cues can promote variations in consumption, acceptance, visual attention, and the creation of expectations by the consumer [39], which can have a halo effect, modifying the perception of flavor and acceptability of food. In this sense, visual properties are critical for holding visual attention and swaying the choosing of products sold by their own appearance, and not by the packaging design. According to previous studies, foods marketed by their own appearance stand out by visual cues of color, texture, and the perception of flavor stimulated by color [40]. Regarding beef, studies have shown that the acceptance of beef with information highlighting a dark red color is higher compared to those with a bright red color (cherry red) [50,51]. Additionally, it was found that intrinsic and extrinsic visual cues significantly influence consumer emotions, hedonic perception, and even food purchase intention, and the provision of additional information, such as names or information on the packaging, can increase the choice and probability of purchase [52].

From a Brazilian perspective, the main visual cues of beef presented to consumers at points of sale can be divided into two groups: (a) regulated: mandatory labelling information by governmental agencies, such as beef cut name, manufacturer name, expiration date, etc.; and (b) strategic: explored in the form of claims or seals by private initiatives.

When buying fresh beef in Brazil, consumers can purchase from one of three situations: meat available in butcher shops and packed according to the consumer's request, chilled meat cuts, and vacuum-packed meat [53]. When purchasing from a butchery or as chilled meat, the consumer has little extrinsic information available about the product—there is a focus mainly on price and visual cues such as appearance. On the other hand, vacuum-packed meats are labelled with regulated visual cues for packaged products, namely: weight, origin, federal inspection seal, product preservation, brand, batch identification, manufacture date, expiration date, and registration number [54]; and strategic visual cues, such as breed, premium quality seals, livestock system, and age, among others.

When purchasing cooked beef (in a restaurant), two main options are available: a la carte dishes prepared with specific beef cuts or all-you-can-eat buffets with various types of meats and beef cuts [55]. In both cases, consumers are provided with specific information on price, regulated visual cues, and strategic visual cues, such as animal breed. Usually, additional information can be obtained from the waiter or even from the appearance and aroma of the meat.

Visual cues of food are determinants in the food choice process; however, the way foods are presented to consumers is not standardized. Previous studies on visual attention attempted to use such data to estimate the amount of consumption, eating behavior, reward process, stimulation of healthy consumption and reducing obesity, differences in dietary perceptions between generations, and effect of expanding areas of exposure to increase sales [39,56–62]. However, few studies have focused on the contribution of visual attention to the probability of choice [52], and studies focusing on beef are scarce.

2.3. The Relationship Between Eye Tracking and Packaging in Consumer Research

Visual attention plays a crucial role in consumer decision-making processes, particularly in environments characterized by high information density such as retail shelves. Eye-tracking technology has emerged as a powerful methodological tool to objectively measure visual attention and explore how packaging elements influence consumer behavior.

Research has consistently shown that packaging design elements—such as color, typography, shape, and visual claims—capture attention and can influence product evaluation and purchase intention [63]. Eye-tracking metrics such as time to first fixation, fixation duration, and number of fixations on areas of interest (AOIs) are commonly used to evaluate which package attributes attract consumer attention and for how long.

It has been demonstrated that visual saliency and branding elements on packaging significantly affect gaze patterns and ultimately influence brand choice. Findings indicate that consumers tend to fixate first and longer on visually salient packages, and that such visual prominence increases the likelihood of product selection [64]. Likewise, strong design features on packages have been shown to not only increase attention but also enhance memory and preference, particularly when integrated into coherent branding strategies [65].

Moreover, eye-tracking studies have revealed that consumers do not process all available visual information on packaging but tend to rely on heuristic cues, often guided by top-down expectations [66]. This behavior underscores the importance of strategically placing key product attributes—such as sustainability claims or nutritional information—in visually dominant positions on the package.

In the context of sustainable packaging, eye-tracking techniques have been used to investigate how eco-labels on food packaging affect consumer attention and choices. Findings suggest that eco-labels can influence purchasing decisions, but only when they are visually accessible and aligned with consumer values [67].

Overall, the integration of eye tracking into packaging research enables a nuanced understanding of the visual mechanisms that drive product perception and choice. These insights are invaluable for marketers and designers aiming to create more effective, attention-capturing packaging in competitive marketplaces.

3. Materials and Methods

3.1. Research Data

The study was conducted in the city of Piracicaba (SP, Brazil) in December 2020, with 23 participants. The participants were randomly selected from the researchers' contact network and through recommendations from other participants. All individuals who participated in the research reported consuming and buying beef at least once a week. The study was conducted in person, with a scheduled time to avoid large groups, in an open space and respecting the World Health Organization (WHO) and local authorities' protocols to prevent COVID-19 infection. Data collection addressed all the requirements of Resolution 510/16 of the National Commission for Research Ethics [68] regarding the protection of research participants and was approved by the Ethics Committee on Research with Human Beings of ESALQ/USP, the researchers' institution. In the experimental space, the participants were given eye-tracking equipment and directed towards an online questionnaire that aimed to collect socioeconomic and consumer behavior data.

3.2. Visual Attention—Eye Tracking

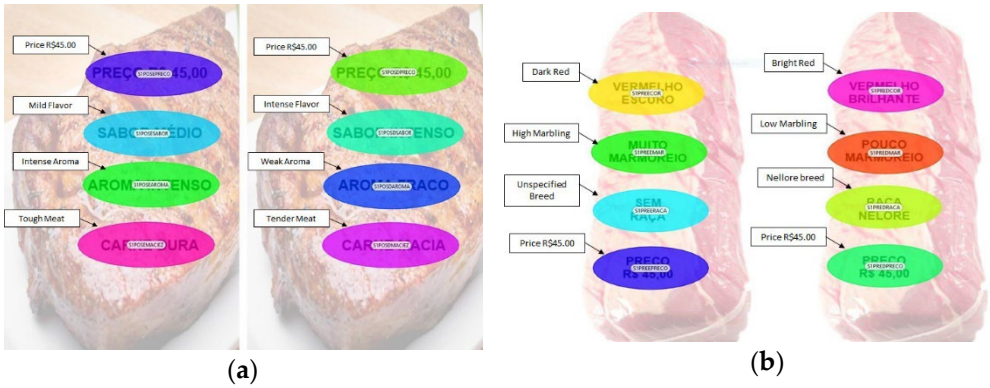
The study presented consumers with nine hypothetical products to choose from according to the protocol [8]. Two purchase situations were used for fresh and cooked beef, as well as a combination of information on visual cues including color, marbling, breed, tenderness, flavor, and aroma, in order to evaluate whether visual attention interferes with the probability of consumer choice.

Two different visual stimuli were created to represent hypothetical products to consumers, a vacuum-packed striploin representing fresh beef and a dish with striploin steak representing cooked beef. The attributes were inserted directly into the images with the

same spacing, font size, and image, mitigating the risks of interference in the readability of the information. Each product was compared by occupying the right and left positions to avoid favoring visual field position, and a total of 18 visual stimuli were presented in each purchasing situation. After visualizing the stimulus, the consumer had to indicate which product was their choice ("product on the right", "product on the left", or "none of the products").

All visual stimuli were presented to participants on Microsoft® PowerPoint® with standard slide (4:3) maximized and used eye-tracking equipment (Tobii T120, Edge Eye, Stockholm, Sweden) with an integrated monitor, on a 17" screen with a resolution of 1280 × 935 pixels and full-screen adjustment. Before starting the presentation of the images to consumers, the equipment was calibrated for each participant, considering equipment distance and height, to ensure better capture of the field of vision. Calibration was performed according to the manufacturer's recommendations.

The images were displayed in sequence and the transition time was 10 s. Amongst the transitions, there was a black background image, with the aim of "cleaning the image" and preparing the consumer for comparison with the following products. Before being presented to consumers, the areas of interest for capturing visual attention in the images were marked around the quality cues studied, with the geometric shape of identical areas for all attributes, according to Figure 1.



(**a**) (**b**)

Figure 1. Areas of interest demarcated: (**a**) cooked beef; (**b**) fresh beef.

Eye tracking metrics used were the tree [18]:

- Time to First Fixation: This refers to the elapsed time until the user's gaze first fixates on a specific area of interest. A shorter time indicates that the visual characteristics of the area are more effective in capturing attention. This metric is particularly valuable when analyzing attention to a specific target [1].
- Fixation Duration: This metric captures the total time and average location of a sequence of fixations within a designated area of interest. It may include multiple fixations and short saccades between them. The fixation sequence is considered complete when the gaze moves outside the area of interest [1].
- Number of Fixations (Visits) on an Area of Interest: A higher number of fixations suggests that the area holds greater significance for the viewer. This measure is closely related to fixation duration and helps assess the total number of fixations in tasks of varying lengths. The number of times an element is fixated on reflects its perceived importance [69,70].

A total of 414 observations were collected from the 23 participating consumers (23 participants × 18 questions = 414 observations) for each situation. These data were initially used as variables of a Logit regression model, making it possible to find their effects on the choice of the visualized product.

3.3. Data Analysis—Logit Model

Logistic or logit regression is used as a nonlinear model designed specifically for binary dependent variables [8]. This regression allows the estimation of the probability associated with the occurrence of a given event, considering a set of explanatory variables [71]; this type of analysis also aims to understand the differences between groups and to estimate the probability that an individual belongs to a particular category, based on a set of explanatory variables [72].

Two logit models were estimated, one for fresh meat and another for cooked meat. The explanatory variables of each model, as well as the details of the logistic equations, are presented in Appendix A. The data related to the variables of the two models (fresh and cooked beef) were considered significant when $p < 0.05$. The analyzes of the models were based on the evaluation of the marginal effect provided by the coefficients of the explanatory variables on the dependent variable. Other models were estimated considering the presence of other variables, using a stepwise method and with the aid of the lowest value for the Akaike Information Criterion (AIC), and the most robust model (best statistical adjustment) was defined for each stage. The lower the AIC, the better the fit of the model [73,74]. A way to evaluate the adjustment of logistic regression to data is to use Pseudo R-Squared. They play a similar role to R^2 in linear regression, by representing the proportion of variation that occurred in the dependent variable that is explained by the model [74]. These values can also be used to compare the performance of competing models, between two equally valid logistic equations. For this, the one with the highest Pseudo-R^2 should be chosen.

4. Results

4.1. Participant's Profile

The participant's profile was obtained by data collection via online surveys (Table 1).

Table 1. Socioeconomic profile of participants.

Information	Description	%	N
Frequency of weekly consumption	Once a week	13%	3
	2 or 3 times a week	61%	14
	4 or 7 times a week	26%	6
Frequency of month purchase	Once a month	9%	2
	2 or 3 times a month	52%	12
	4 or 5 times a month	22%	5
	6 or more times a month	17%	4
Gender	Male	57%	13
	Female	43%	10
Age range (years)	18–30	74%	17
	31–40	26%	6
Education	High School completed	13%	3
	University completed	57%	13
	Postgraduate	30%	7
Average income (month)	USD 200.00–600.00	61%	14
	USD 601.00–1000.00	26%	6
	USD 1001.00–3000.00	13%	3
Location	São Paulo	96%	22
	Others	4%	1

The most prominent participants included men aged 24 to 30 years, with a college degree, a minimum frequency of purchase of 2 times a month, weekly consumption of beef

2 to 3 times per week, living in the state of São Paulo, Brazil, and a salary ranging from USD 200.00–600.00, which corresponded to approximately 22% of the research participants.

4.2. Visual Attention—Fresh Beef

The results obtained from the Logit model for fresh and cooked beef are presented in Tables 2 and 3, respectively. When comparing the predicted values obtained with the estimated models for fresh beef to the observed values of the sample, an accuracy index of 95.19% was obtained, which is considered a good fit [75].

Table 2. Estimates of Logit model coefficients for fresh beef and respective values of marginal effects.

Variables	Coefficients	Standard Deviation	*p*-Value	MgE #
Intercepto	17.359	4.2607	0.0000 ***	-
FRESH.PRICE	0.0952	0.0370	0.0101 **	0.0318
CBROWNCO	−3.4719	1.1442	0.0024 ***	−0.1116
FRESH.FBRIGHTCO	−0.5713	0.2405	0.0175 **	−0.0050
FRESH.FBROWNCO	−0.7133	0.3780	0.0592 *	−0.0062
FRESH.TDARKCO	3.7014	1.9604	0.0590 *	0.0325
FRESH.TNELLOREB	−3.3003	1.6080	0.0401 **	−0.0289
FRESH.TWITHOUTB	13.2524	4.4611	0.0029 ***	0.1163
FRESH.TBROWNCO	−2.8524	1.3094	0.0293 **	−0.0250
FRESH.VDARKCO	−1.7553	0.6874	0.0106 **	−0.0154
FRESH.VSMALLMAR	−2.4407	0.7195	0.0007 ***	−0.0214
FRESH.VMODERATEMAR	−0.9295	0.41418	0.0248 **	−0.0081
FRESH.VABUNDANTMAR	−1.6202	0.4790	0.0007 ***	−0.0142
FRESH.VPRICE380	−1.1141	0.5596	0.0465 **	−0.0097
FRESH.VWITHOUTB	−5.4550	1.5222	0.0004 ***	−0.0479
FRESHQCONS_C	5.3391	2.0705	0.0099 ***	0.0265
FRESHQPURCHASE_D	−7.3969	2.0462	0.0004 ***	−0.7977
MED_COMP	−1.4765	0.5006	0.0031 ***	−0.0129
n				229
AIC				92.213
Mc Fadden (Pseudo-R2)				0.74
Cox–Snell (Pseudo-R2)				0.51
NagelKerke (Pseudo-R2)				0.83

MgE: marginal effect; * *p* value < 0.10; ** *p* value < 0.05; *** *p* value < 0.01.

Appendix B describes the guidelines that were given to consumers regarding breed, color, and marbling. For the item color and marbling, photos were provided with guidelines.

First Fixation (Table 2)

Considering the first fixation, two visual cues related to color were significant: FRE.FBRIGHTCO and FRE.FBROWNCO. In this study, visual cues for fresh beef including color, breed, marbling, and price were considered; however, the information about color was the only one found to be significant for first fixation. Consumers who first fixated on color information had a 0.50% lower purchase probability after looking at visual cue

information on FRE.FBRIGHTCO and 0.62% lower probability after looking at visual cue information on FRE.FBROWNCO.

Table 3. Estimates of Logit model coefficients for cooked beef and respective values of marginal effects.

Variables	Coefficients	Standard Deviation	*p*-Value	MgE #
Intercepto	1.14007	1.62154	0.4820 ND	-
COOK.PRICE	0.16837	0.06606	0.0108 **	0.0050
COO.TOUGHMC	−2.21684	0.86441	0.0103 **	−0.1660
COO.FTOUGH	−0.88719	0.20065	0.0000 ***	−0.0266
COO.FWEAKFLAVOUR	−0.36660	0.15630	0.0190 **	−0.0110
COO.VPRICE580	−0.99133	0.32722	0.0024 ***	−0.0297
COO.VPRICE900	−2.28778	0.65485	0.0005 ***	−0.0686
COO.VINTENSEFLAVOUR	−0.61987	0.29383	0.03489 **	−0.0186
COO.FREQCONSU_B	2.09243	0.84142	0.0128 **	0.0867
COO.FREQPURCHASE_D	−1.74068	0.87018	0.0454 **	−0.0944
N				226
AIC				85.109
Mc Fadden (Pseudo-R2)				0.68
Cox–Snell (Pseudo-R2)				0.46
NagelKerke (Pseudo-R2)				0.77

MgE: marginal effect; ** *p* value < 0.05; *** *p* value < 0.01; ND: not significant (*p* value > 0.10).

Total Fixation (Table 2)

Considering the total time (seconds) that participants fixated on specific attributes, visual cues including color and breed were significant: FRE.TDARKCO, FRE.TBROWNCO, FRE.TNELLOREB, and FRE.TWITHOUTB. The information on visual cues FRE.TDARKCO and FRE.TWITHOUTB increased the probability of choice by ~3% and ~12%, respectively. However, FRE.TNELLOREB and FRE.TBROWNCO reduced the probability of choice by ~3% and ~2.5%, respectively. Fixation on color, before the presentation of the products in the equipment, was studied; consumers were asked to visualize a color pattern, guided by the authors.

Total Number of Fixations (Table 2)

Considering the number of times that each participant fixated on an AOI (visit), color, marbling, price, and breed were significant, namely FRE.VDARKCO, FRE.VSMALLMAR, FRE.VMODERATEMAR, FRE.VABUNDANTMAR, FRE.VPRICE380, and FRE.VWITHOUTB.

4.3. Visual Attention—Cooked Beef

Table 3 presents the results of the final Logit model estimated for cooked beef. Regarding the predicted values obtained with the estimated model for cooked beef, when comparing them with the observed values of the sample, an accuracy index of ~96.7% concordance was established, which indicates a good fit of the data [75].

First Fixation (Table 3)

Considering the first fixation, tenderness and flavor were significant: COO.FTOUGH and COO.FWEAKFLAVOUR. Consumers who first fixated on tenderness information re-

duced the purchase probability by 2.6% by looking at visual cue information COO.FTOUGH and by 1.1% after looking at visual cue information COO.FWEAKFLAVOUR.

Total Fixation (Table 3)

The best-fitting model did not present any significant variables related to "total fixation" metrics for explaining the choice of cooked meat.

Total Number of Fixations (Table 3)

Considering the number of times that individuals visited an AOI, the information regarding price and taste was significant: COO.VPRICE580, COO.VPRICE900, and COO.VINTENSEFLAVOUR. Only two levels of price and one level of flavor had a high frequency of visits.

Regarding COO.VPRICE580 and COO.VPRICE900, each time the consumer revisited the AOI, there was a reduction in the probability of choice by 2.97% and 6.86%, respectively. To a lesser extent, on the COO.VINTENSEFLAVOUR: each time the consumer revisited the AOI, there was a reduction in the probability of choice by 1.86%.

5. Discussion

Knowledge about the socio-economic profile of participants is very important in research such as this. For this, firstly, the possible participants were indicated by people that knew what the focus would be. Then, these participants were randomly chosen, resulting in a total of 23 individuals. The indications were to better select a priori the education of the participants, having, at least, graduated from high school. Almost half belong to the same gender, with 57% being male and 43% being female (Table 1). Differences were found among gender about specific preferences and attitudes towards meat color; for instance, female participants more commonly held skeptical attitudes towards red meat and meat-eating [76].

Parameters such as frequency of consumption and average income are very important to measure, mainly given that beef is an expensive component of a meal. The consumer is motivated by both internal and external influences, at the time of purchase, and the external part is determined by social class, culture, family, and the groups that they are included [77]. In this study, beef was typically consumed by the participants two or three times a week (61%), and at least once a week (Table 1).

Visual attention was measured both in fresh and cooked beef. First, observations regarding the fresh meat will be discussed, as the results of both were analyzed separately. For fresh beef, as mentioned above, the accuracy index was very representative with 95.19%, comparing predicted values with the estimated models.

The results of the first fixation, the aspect that the participants first pay attention to, were significant, regarding fresh beef, for the FRE.FBRIGHTCO and FRE.FBROWNCO, stimulus of beef with bright red color and brown color, respectively. This was the parameter that they perceived more compared to breed, marbling, and price. This was corroborated with other studies [39,40]. These results indicate that, for the sample of consumers studied, the color of fresh beef is the visual cue that attracts their visual attention of during the first fixation.

Changes between the bright red color (oxymyoglobin) and brown color (metmyoglobin) of fresh beef can be considered as "extreme" changes [78]. Brazilian consumers typically find dark-colored beef (deoxymyoglobin) at the point of sale [79]. It is suggested that the first fixation is concentrated on the color. This can be due to the difference from what is typically expected, which can cause distrust [9]. Alternatively, a possible justification for why other quality cues were not significant when first fixating may be the lack

of understanding of the consumer about those parameters or not being able to determine other attributes for the beef choice [13].

Regarding the time to first fixation, which is the first stimulus displayed, the color was the main parameter that was associated with it, as discussed above. However, regarding the total fixation, which is the duration of all fixations within an AOI, or within all AOIs belonging to an AOI group [80], it was indicated that the respondents focused significantly on color and breed attributes (FRE.TDARKCO, FRE.TBROWNCO, FRE.TNELLOREB, and FRE.TWITHOUTB), regarding fresh beef. The dark red color and any breed information increased the purchase chance while the information regarding brown color and Nellore breed reduced it.

Regarding FRE.TDARKCO, the increased purchase probability as a consequence of visual attention increase may be motivated by the consumer's familiarity with that information [10,81]. For FRE.TBROWNCO, the reduction in the probability of choice may be due to doubts in the interpretation of this information, because it is known that the color of beef can change according to the type of packaging—typically, vacuum-packed beef is brown in color [82,83]. In addition, microbiological, physicochemical, or temperature changes may also give beef a brown color [84,85]. Thus, it can be posited that the consumer's preference may be influenced by their knowledge about color variations in beef, but also due to their concerns with quality, which can be correct.

The increase in the probability of choice when viewing the information on FRE.TWITHOUTB (total time of fixation in the AOI related to the stimulus of beef without any breed information) may indicate that the consumers participating understand that less information about beef is more attractive and facilitates their choice; thus, visual cues of the beef itself can be a sufficient source of information, as reported by [40,86]. There was a reduction in the probability of sale caused by the information on FRE.TNELLOREB, which may be due to previous negative experiences associated with beef from the Nellore breed, lack of knowledge about the contribution of the breed to the quality of beef, or even the habit to consume beef without the identification of the breed [41,87,88].

It is also possible that some consumers have preferences for specific breeds, such as Angus (Bos taurus taurus) than Nellore (Bos taurus indicus), as it has been proven by many authors [89,90] that they present more tender meat. Meat from Bos indicus crossbred cattle is less tender than meat from Bos taurus cattle, regardless of marbling score [91]. This can lead to decreased acceptance of Nellore meat by consumers, especially since such research is more feasible today. Moreover, advertising for the Brazilian Angus, the main Bos taurus breed in Brazil, uses tenderness as a key selling point.

The correlation found between total fixation time and probability of choice is similar to the findings of a study in which an increase in visual attention was found to increase the probability of choice [10]. The total number of fixations, which is the number of times that each participant fixated on an AOI, with respect to fresh beef and considering the parameters color, marbling, price, and breed, were FRE.VDARKCO, FRE.VSMALLMAR, FRE.VMODERATEMAR, FRE.VABUNDANTMAR, FRE.VPRICE380, and FRE.VWITHOUTB.

Analyzing the information on FRE.VDARKCO, it was observed that the probability of the consumer choosing beef with this information was reduced by 1.54% each time the individual revisited fixating on the dark red color. The return of the consumer to the same visual cue indicates importance, doubt, or difficulty in understanding the attribute [18,32]. Additionally, the understanding of information can be facilitated or hindered according to the level of consumer involvement with beef [2,88]. Participants' level of involvement with fresh and cooked beef was not measured.

The information on the visual cues FRE.VSMALLMAR, FRE.VMODERATEMAR, and FRE.VABUNDANTMAR reduced consumer choice by 2%, 0.8%, and 1.4% at each return fixation, respectively. This study indicated that all levels of marbling were important, and they reduced the probability of purchase. These results differ partially from the findings of [92], who identified a higher preference for beef with lower fat content, and in this case, lower marbling lead to more rejection. These authors found that beef variation in fat content can produce different patterns in terms of visual attention and product choice; the present study found the same pattern for all levels of marbling. The differences found may be due to different cultural habits since the study [87] was conducted with Portuguese consumers. It is important to consider the level of knowledge about the contribution of marbling to flavor, succulence, and tenderness of beef [92]. Consumers who make health-based food choices are more likely to seek information that helps them assess the healthiness of products but may encounter difficulties related to knowledge and quality cues of the product [93,94].

Regarding FRE.VPRICE380, the high number of visits indicates the importance of this visual cue for consumers, which may represent a reduction in the probability of choice due to mistrust and difficulty in identifying trade-offs. In Brazil, one kg of beef typically costs more than USD 3.80. When consumers find cheaper prices, they tend to distrust the establishment or the characteristics of the product; this is reflected in the reduction in the probability of purchase by 0.97% each time the individual fixates on the price. These results agree with the study [8], who also identified a reduction in the probability of choice for beef with lower prices. Additionally, consumers make decisions based on a variety of quality and visual cues. For beef, a range of products are available, and consumers need to evaluate both regulated and strategic visual cues before deciding which confers greater complexity [27].

Regarding breed, some consumers may understand that the presence of information about the breed can help them distinguish between beef quality. Regarding the information on FRE.VWITHOUTB, the high number of visits to this attribute may indicate distrust or lack of understanding of differences between breeds, as there was a reduction in the probability of choice by 4.79% for each fixation, or that the breed has no influence on their decision. This can be attributed to the fact that in Brazil, the purchase of the meat often occurs directly in the butcher shops that offer a variety of cuts fresh or cooked, without the label, and some information about breed, gender, age, and others.

The dark color of beef, without breed information, showed different behaviors between the metrics. When evaluated for total fixation, they increased the probability of choice; however, when evaluated considering the number of fixations (visits), the probability of choice was reduced.

For both the total fixation time and the number of visits, greater visual attention reduced the probability of choice for all visual cue information. One hypothesis may be that beef consumers are more sensitive to information about visual cues, leading them to reject beef, than they are to information that is of interest. It is likely that the lack of familiarity with the information presented to consumers may justify difficulty in interpreting the information, resulting in a preference for not buying beef with unavailable information.

Considering the first fixation about cooked beef, only tenderness and flavor were significant: COO.FTOUGH and COO.FWEAKFLAVOUR. The participants contemplated visual cues including flavor, aroma, tenderness, and price. The most significant for first fixation was ‘weak flavor’ and ‘tough beef’. First fixation on these attributes suggests that consumers looking for cooked beef primarily considered information on taste and tenderness. Those with weak flavor and tough beef reduced the purchase probability by 2.6% and 1%, respectively, as this is negative information. The findings agree with

research [8] that evaluated the same visual cues through online research in cooked beef and identified which ones could increase the probability of choice. These authors found that there is a significant reduction in the probability of choice when the product has weak flavor and a tough consistency. It included negative information on the product description; this is not likely to occur in a real purchase situation, but we found it important to highlight that visual cues that refer to undesirable characteristics should be the target of future studies.

For the metric referring to time of the first fixation, the visual cues that were most significant were tough meat and weak flavor, again demonstrating that, contrary to the behaviors identified for fresh beef, consumers of cooked beef are more interested in avoiding meat beef with negative information about attributes. These results are in accordance with other research [8]. A possible explanation for this may be the repeated experiences of beef consumption with these negative characteristics.

Regarding cooked beef, the number of times that individuals visited an AOI was analyzed, and it was found to be significant for price and taste: COO.VPRICE580, COO.VPRICE900, and COO.VINTENSEFLAVOUR. Prices of USD 5.80 (COO.VPRICE580) and USD 9.00 (COO.VPRICE900) reduced the probability of choice by 2.97% and 6.86%, respectively. The participants were more resistant to choosing more expensive beef. A decrease in the probability of purchase for beef with a price of USD 9.00/kg was also found [8].

Considering COO.VINTENSEFLAVOUR, the high number of returns to this information may indicate consumer preference. It was observed that the probability of the consumer choosing beef reduces by 1.86% each time they revisit the AOI related to intense flavor.

Unlike fresh beef, metrics referring to the number of return fixations of cooked beef were composed of information about attributes that generate difficulty in understanding or differentiation (i.e., breed). For cooked beef, the total time of fixation on AOIs was not significant, so they were not included in the model. A possible justification for this may be the greater understanding and familiarity of consumers with visual qualities of cooked beef compared to fresh beef [9,10]. Interestingly, cooked beef is usually presented with little information available, so the increase in information in the study may have caused confusion and difficulty, because they are desirable quality cues, but not normally reported.

6. Conclusions

Visual attention is the process by which consumers use visual attributes to determine if they are interested in a product. These may be attributes that consumers know, and these can either increase or reduce the probability of choice. Attributes regarding color and breed maintained more attention among the consumers than the others, specifically, dark color and any information about the breed. The other visual attributes studied reduced the probability of consumers making a choice, which may be an indication that the participants of this study focused visual attention on the information that they reject as the brown color; it was also proved that the consumers would like to have more information, such as breed, and that this can be more representative of the purchasing decisions of Brazilian consumers.

Information on marbling and different breeds should be highlighted if it is clear to the consumer what the benefit of these attributes is for the final product. It may therefore be beneficial to include this information as explanatory texts on the packaging. Legislation on strategic visual cues can be implemented, so mandatory additional information should be placed on the packaging, or standardization of specific information should be enforced to highlight relevant health attributes.

This study contributes to a better understanding of how visual attention influences consumer decision-making in the context of beef purchases, integrating eye-tracking technology with experimental design to capture non-conscious responses. By identifying which visual cues—such as color, marbling, breed, price, tenderness, and flavor—drive atten-

tion and affect choice probability, the findings confirm that visual information is a key determinant in food selection, particularly in fresh and cooked meat contexts.

These insights have practical implications for product packaging design, retail marketing strategies, and food labeling practices. For instance, the prominence of color in driving attention toward fresh beef suggests that enhancing the visual appeal of product displays can increase purchase likelihood. In the case of cooked beef, the findings emphasize the relevance of flavor and tenderness cues, which can be strategically highlighted in visual communication and promotional materials.

For future research and applications, these findings support the expansion of eye-tracking methods to other food categories and retail environments. Moreover, they encourage the integration of psychological metrics and biometric tools in market analysis, allowing a more comprehensive and precise approach to understanding consumer behavior and optimizing visual merchandising.

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Conflicts of Interest: Author Bruna Alves Malheiros was employed by the company Symrise. Author Carolina Naves Aroeira was employed by the company AgroProx. Author Lilian Maluf de Lima was employed by the company Pecege Institute. The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Appendix A

Detailed description of the models for fresh and cooked meat, according to the explanatory variables.

Thus, for the fresh beef model:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_{17} X_{17} + u_t$$

Y is the binary variable where Y = 1 characterizes the consumer who chose the product (right or left) of the stimulus visualized in fresh beef; Y = 0 characterizes the consumer who chose neither the product on the right nor the product on the left of the slide; β_0, $\beta_1, \beta_2, \ldots \beta_{17}$ are the parameters of the model to be estimated (coefficients) and it refers to the term of stochastic error. The values assumed by X are described below:

X_1 = "FRESH.PRICE", price that the participant would be willing to pay for the beef visualized in the stimulus, assuming values of USD 3.80, USD 5.80, and USD 9.00;

X_2 = "FRESH.BROWNCO", brown-colored beef, assuming value 1 when the beef visualized by the participant has a brown color and value 0 when the beef has dark red or bright red color;

X_3 = "FRESH.FBRIGHTCO", total time (seconds) of the first fixation in the AOI, related to the stimulus of beef with bright red color;

X_4 = "FRESH.FBROWNCO", total time (seconds) of the first fixation in the AOI related to the stimulus of the beef with brown color;

X_5 = "FRESH.TDARKCO", total time (seconds) of fixation in the AOI related to the stimulus of beef with dark red color;

X_6 = "FRESH.TNELLOREB", total time (seconds) of fixation in the AOI related to the stimulus of beef from animals of the Nellore breed;

X_7 = "FRESH.TWITHOUTB", total time (seconds) of fixation in the AOI related to the stimulus of beef without any breed information;

X_8 = "FRESH.TBROWNCO", total time (seconds) of fixation in the AOI related to the stimulus of beef with brown color;

X_9 = "FRESH.VDARKCO", number of times that the individual fixates on the AOI related to the stimulus of beef with dark red color;

X_{10} = "FRESH.VSMALLMAR", number of times that the individual looks at the AOI related to the stimulus of beef with small marbling;

X_{11} = "FRESH.VMODERATEMAR", number of times that the individual looks at the AOI related to the stimulus of beef with moderate marbling;

X_{12} = "FRESH.VABUNDANTMAR", number of times that the individual looks at the AOI related to the stimulus of beef with abundant marbling;

X_{13} = "FRESH.VPRICE380", number of times that the individual looks at the AOI related to the stimulus of beef price of USD 3.80;

X_{14} = "FRESH.VWITHOUTB", number of times that the individual looks at the AOI related to the stimulus of beef without breed information;

X_{15} = "FREQCONS_C", frequency of beef consumption in the week, assuming value 1 when consumption is 4 to 5 times a week and value 0 when otherwise;

X_{16} = "FREQPURCHASE_D", frequency of purchase of beef in the month, assuming value 1 when the frequency of purchase is 6 or more times per month and value 0 when otherwise;

X_{17} = "MED_COMP", average of the scores assigned by the participants during the product choice experiment. These scores[1] refer to information on comparisons of knowledge of the general population with the interviewed consumer.

For the cooked beef model, the values assumed by X are described below:

X_1 = "COOK.PRICE", price that the consumer would be willing to pay for the beef visualized in the stimulus, considering values of USD 3.80, USD 5.80, and USD 9.00;

X_2 = "COOK.FREQCONS_B", frequency of beef consumption in the week, assuming value 1 when consumption is 2 to 3 times a week and value 0 when otherwise;

X_3 = "COOK.FREQPURCHASE_D", frequency of buying beef in the month, assuming value 1 when the purchase is 6 or more times per month and value 0 when otherwise;

X_4 = "COOK.TOUGHMC", tough beef, assuming value 1 when the beef visualized by the consumer is tough and value 0 when otherwise (tender or very tender beef)

X_5 = "COOK.FTOUGH", total time (seconds) of the first fixation in the AOI related to the stimulus of tough beef;

X_6 = "COOK.FWEAKFLAVOUR", total time (seconds) of the first fixation in the AOI related to the stimulus of beef with weak flavor;

X_7 = "COOK.VPRICE580", number of times that the individual visits the product and fixates on the AOI related to the stimulus of beef price of USD 5.80;

X_8 = "COOK.VPRICE900", number of times that the individual visits the product and fixates on the AOI related to the stimulus of beef price of USD 9.00;

X_9 = "COOK.VINTENSEFLAVOUR", number of times that the individual visits the product and fixates on the AOI related to the stimulus of beef with intense flavor.

Appendix B

BREED

A group of animals that share similar physical and genetic characteristics.

Non-Breed	Nellore Breed	Angus Breed
Undefined origin	Originating from India	Originating from Scotland
Undefined hardiness	It is the hardiest breed	It is a less hardy breed
Undefined heat tolerance	Breed with high heat tolerance	Breed with low heat tolerance
Represents 10% of the total cattle herd in Brazil	Represents 80% of the total cattle herd in Brazil.	Represents 10% of the total cattle herd in Brazil.

COLOR

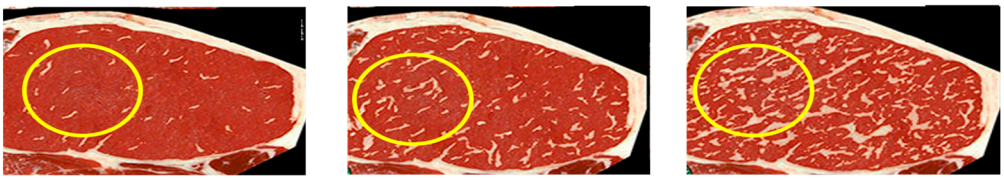
It can be observed on the surface of the meat.

Bright red Brown Dark red

MARBLING

It refers to the intramuscular fat within the meat.

Low marbling High marbling Moderate marbling



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