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Consumer Evaluations and Warner-Bratzler Shear Force of Foodservice Tenderloin Steaks Sourced From Different Market Classes of Domestic and Imported Beef

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Abstract: The objectives of this study were to evaluate consumer sensory ratings and objective tenderness of 6 different sources of tenderloin steaks for the foodservice industry. Tenderloins were from 6 sources: (1) United States Department of Agriculture (USDA) Choice, (2) USDA Select, (3) white-fat cow, (4) yellow-fat cow, (5) Uruguay, and (6) Australia. Fresh tenderloins ($n = 162$; 27 tenderloins × 6 sources) were collected and fabricated into 6 steaks. Steaks were designated for consumer sensory analysis or Warner-Bratzler shear (WBS) force. Consumers evaluated sensory steaks for juiciness like/dislike, flavor like/dislike, tenderness like/dislike, overall like/dislike, and provided qualitative descriptors. Consumers rated white-fat cow steaks, Australian steaks, and USDA Choice steaks among the greatest ($P < 0.05$) for overall liking. White-fat cow steaks and yellow-fat cow steaks had lower ($P < 0.05$) WBS force values than Uruguayan steaks. These findings suggest that tenderloins from sources other than USDA Choice may provide cost-effective options for foodservice markets. Depending on market prices, white-fat cow and Australian carcasses could both serve as economically suitable sources of tenderloins for foodservice establishments while still providing a similar eating experience to USDA Choice carcass steaks.

Key words: beef, consumer panels, tenderness, Warner-Bratzler shear force, tenderloin, foodservice
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Introduction

In the United States (US), the beef tenderloin (M. psoas major) is a highly sought-after portion of the beef carcass and is among the most tender beef cuts (Belew et al., 2003). The initial National Beef Tenderness Survey, conducted by Morgan et al. (1991), revealed that consumers rated beef tenderloin steaks greatest in sensory tenderness evaluations compared to other cuts. This trend continued in the most recent National Beef Tenderness Survey, where consumers again rated the tenderloin as the most tender retail steak (Gonzalez et al., 2024). Additionally, when comparing objective Warner-Bratzler shear (WBS) force of different beef muscles, the tenderloin consistently falls within the "very tender" category (Belew et al., 2003) and had the lowest WBS force in the 2022 National Beef Tenderness Survey of retail steaks (Gonzalez et al., 2024).

Foodservice establishments typically use United States Department of Agriculture (USDA) Choice and USDA Prime tenderloins, which are some of the highest-priced subprimals and steaks in the marketplace. As price point and product availability influence procurement decisions for tenderloins, foodservice establishments seek to find additional cost-effective sources for consumers. Potential alternatives for foodservice beef tenderloin supply could include USDA Select quality grade, grass- and grain-finished cows, and import markets such as those from Australia and Uruguay. On April 26, 2024, the market price for USDA Choice tenderloins

(Institutional Meat Purchase Specifications [IMPS] 190) was $31.95 per kg (U.S. Department of Agriculture, 2024a), in stark contrast to beef cow tenderloins (IMPS 190), which ranged from $7.56 to $11.77 per kg for the same week (U.S. Department of Agriculture, 2024b). Although current prices of imported tenderloins were not readily available, industry conversations suggest that numerous countries could provide cost-effective products compared to native US beef tenderloins. In addition to price, palatability characteristics are also important. Australian consumers value many of the same palatability traits as Americans, with flavor and tenderness being the most important factors (Egan et al., 2001), indicating that acceptable consumer eating experiences may be sourced from import markets.

It is of interest to determine if incorporating additional beef tenderloin sources into the foodservice supply could provide a cost-effective tenderloin option for consumers while still delivering a satisfying eating experience. To fulfill consumer expectations for palatability and cost, it is imperative for foodservice establishments to understand the possible variability in tenderloin sources. Therefore, the objectives of this study were to evaluate 6 different sources of tenderloin steaks and determine the effect of source on consumer sensory ratings and objective tenderness measurements. Findings from this research may allow foodservice establishments to make effective purchasing decisions that balance palatability and cost differences among tenderloin sources.

Materials and Methods

All consumer sensory panel procedures were approved by the Texas A&M Institutional Review Board for the Use of Humans in Research (Protocol number: STUDY2024-0286).

Product collection

A collaborating purveyor purchased fresh beef tenderloins, similar to IMPS Item Number 189A, Beef Loin, Tenderloin, Full, Side Muscle On, Defatted, or IMPS Item Number 190, Beef Loin, Tenderloin, Full, Side Muscle Off, Defatted (U.S. Department of Agriculture, 2020), from 6 sources: (1) USDA Choice (U.S. Department of Agriculture, 2017), (2) USDA Select (U.S. Department of Agriculture, 2017), (3) white-fat cow (industry term used to describe products primarily from dairy cows where high-concentrate feeding results in external fat that is generally white in appearance and carcasses are similar in quality to USDA Select or higher), (4) yellow-fat cow (industry term used to describe products primarily from beef cows where forage-based feeding results in external fat that is generally yellow in appearance and carcasses are similar to USDA Utility or USDA Cutter), (5) Uruguayan (imported products from the country of Uruguay where the cattle are primarily forage-finished), and (6) Australian (imported products from the country of Australia). For imported tenderloins, the postmortem aging time was approximately 14 d in the country of origin, 30 d for transport to the US, and 10 d in the US to clear customs and be transported to the purveyor, for a total of 50 to 60 d postmortem aging. The beef tenderloins were converted to IMPS Item Number 190B Tenderloin Full, Side Muscle Off, Center-Cut, Skinned (IM) (U.S. Department of Agriculture, 2020).

Steak fabrication

From each tenderloin, 6 steaks, similar to IMPS Item Number 1190B, Beef Loin, Tenderloin Steak, Full, Side Muscle Off, Center-Cut, Skinned (IM), were hand cut (~2.54-cm thick) for a total of 972 steaks (n = 27 whole tenderloins per source, 162 whole tenderloins total). The first steak was cut approximately 10 cm from the caudal end of the M. psoas major, and subsequent steaks were cut moving towards the cranial end. Three steaks from each tenderloin were used for consumer sensory panel evaluation, 2 steaks were used for WBS force analysis, and one steak was held in reserve. Steaks were selected for their respective procedures at random.

Packaging

Steaks from each tenderloin were labeled and vacuum packaged together with a roll stock machine (Reiser Repak RE20, Canton, MA, USA) using Cryovac brand films (Sealed Air, Food Care Division, Charlotte, NC, USA) top web: Item No. T7230B, 3.0 mil with an oxygen transmission rate (OTR) of 4 [cc/m2/d @ 23°C, 0% relative humidity (R.H.)] and bottom web: Item No. T7045B, 4.5 mil with an OTR of 3 [cc/m2/d @ 23°C, 0% R.H.]. Then, steaks were boxed, placed into plastic insulated containers, and transported under refrigerated conditions to the Rosenthal Meat Science and Technology Center at Texas A&M University (College Station, TX, USA). Upon arrival, steaks were stored (3 ± 1°C) until subsequent cooking, consumer panels, and WBS

analysis following Research Guidelines for Cookery, Sensory Evaluation, and Instrumental Tenderness Measurements of Meat (American Meat Science Association, 2016). Storage time ranged from 6 to 15 d, with sources being equally distributed across panel sessions and WBS.

Cooking of steaks

Before cooking steaks for consumer panels, a 4-digit sample ID was generated using a random number generator (Microsoft Excel; Microsoft Corp., Redmond, WA, USA) and checked for duplicates. Steaks for consumer sensory evaluation and WBS force testing were cooked in the same manner. Steaks were cooked on a Star International commercial flat top grill (Max Model 536TGF, St. Louis, MO, USA). The grill was preheated for 30 min to a surface temperature of approximately 177°C. After placing steaks on the grill, they were flipped when internal temperatures reached 35°C and then cooked to final temperatures of 70°C. Internal steak temperatures were monitored using digital thermometer probes (ThermoWorks ThermoPop, American Fork, UT, USA). For each steak, pre- and post-cook weights were recorded to calculate cook yields.

If not immediately served, steaks assigned to consumer sensory analysis were held warm in a Hatco Cook & Hold Oven set at 60°C (Model CSC-10, Hatco Corporation, Milwaukee, WI, USA) for no longer than 20 min. After cooking, steaks designated for WBS force were labeled, placed on plastic trays, covered in plastic wrap, and stored in a cooler (~3 ± 1°C) for 12 to 18 h before further analysis.

Consumer panels

Individuals from the Bryan/College Station area were notified of the current study via recruiting emails and the use of an existing consumer database. Interested individuals completed a Qualtrics survey (Qualtrics, Provo, UT, USA) to identify interest, availability, and ensure beef consumption. From the survey responses, consumer panelists ($n = 108$; 9 panels of 12 panelists each) were selected. Upon arrival at the sensory facility, all panelists signed a consent form and completed a demographic questionnaire (Table 1). Panelists were then provided with a brief overview of the sampling procedure.

Before serving, cooked steaks were trimmed of external fat and heavy connective tissue and then cut into cuboidal (1.27 cm × 1.27 cm × steak thickness) sections. The serve order was variable, and cuboidal sections from steaks within a specific serve order and source were mixed. Due to the concern with sensory fatigue, each panelist only evaluated 6 tenderloins—one per source.

Samples were served to panelists seated within individually partitioned sensory areas under red theater lighting to prevent panelist bias for the degree of doneness. Nabisco Unsalted Tops Premium Saltine Crackers (Kraft Foods Global, Inc., East Hanover, NJ, USA) and double-distilled deionized water were used as palate cleansers between each sample. When evaluating samples, panelists utilized 9-point scales

Table 1. Demographic attributes of consumer sensory panelists ($n = 108$).

Item	n[1]	%
Gender		
Male	45	41.7
Female	63	58.3
Did not disclose	0	
Age, y		
< 20	13	12
21 to 25	26	24.1
26 to 35	34	31.5
36 to 45	12	11.1
46 to 55	10	9.3
56 to 65	11	10.2
≥ 66	2	1.8
Working status		
Not employed	5	4.3
Full-time	48	41.7
Part-time	12	10.4
Student	50	43.5
Annual household income, US$		
< 25,000	26	24.5
25,000 to 49,999	15	14.2
50,000 to 74,999	16	15.1
75,000 to 99,999	16	15.1
≥ 100,000	33	31.2
Food allergy or dietary restrictions		
No	100	92.6
Yes	8	7.4
Self/Immediate family works for a food company		
No	105	97.2
Yes	3	2.8
Ethnicity		
Caucasian	72	63.7
Hispanic	23	20.3
Asian or Pacific	12	10.6
Black	1	<1
American Indian	1	<1
Other	4	3.5

[1]Number of responses.

(1 = dislike extremely, 9 = like extremely) for overall like/dislike, flavor like/dislike, tenderness like/dislike, and juiciness like/dislike, and were also presented with an opportunity to describe what they liked most and/or least about the sample. Panelists received a $25 gift card for participating in this study.

WBS force

Before WBS force evaluation, cooked steaks were removed from the cooler (~3 ± 1°C) and allowed to equilibrate to room temperature. Each steak was trimmed of any visible external fat and connective tissue to expose the muscle fiber orientation. A minimum of 3 cores (1.27-cm diameter) were removed from each steak parallel to the muscle fibers using a hand-held coring device. Cores were sheared once, perpendicular to the muscle fibers, on a United Testing machine (United SSTM-500, Huntington Beach, CA, USA) at a cross-head speed of 200 mm/min using a 10-kg load cell, and a 1.02-mm-thick V-shaped blade with a 60° angle and a half-round peak. The peak force (kg) needed to shear each core was recorded, converted to Newtons (N), and the mean peak shear force of the cores was used for statistical analysis. The equipment was calibrated before the start of data collection, and calibration was checked after shearing approximately every 30 cores.

Statistical analysis

Data were analyzed utilizing JMP Pro (v. 15.2.1; SAS Institute, Cary, NC, USA). Source ($n = 6$) was defined as the fixed effect. The Fit Model Standard Least-Squares function was used for one-way analysis of variance, and mean comparisons were conducted using Student's t test at an alpha of $P < 0.05$. Data were generated and reported by tenderloin × source for all models. For the Fit Model Standard Least-Squares function, "*Y, response*" variable was the effect being analyzed, and "*X, factor*" was the tenderloin source. Microsoft Excel (Microsoft Corporation, Redmond, WA, USA) was used to calculate frequencies for consumer panelists' demographics.

Results and Discussion

Consumer sensory panel

Least squares means of consumer ratings for beef palatability attributes (overall like/dislike, tenderness like/dislike, flavor like/dislike, and juiciness like/dislike), stratified by tenderloin source, are presented in Table 2. For overall liking, white-fat cow steaks, Australian steaks, and USDA Choice steaks had similar ratings ($P > 0.05$), whereas USDA Select steaks and Uruguayan steaks had among the lowest ($P < 0.05$) ratings. Although the origin of cow tenderloins in the current study is unknown, when comparing dairy cattle to beef cattle, dairy cattle often have higher marbling scores and water holding capacity (Pfuhl et al., 2007). In the current study, white-fat cow steaks may have performed so well due to the improved meat quality characteristics that would be associated if the

Table 2. Least squares means ± SE for sensory panel ratings[1] of steaks stratified by source[2] ($n = 108$ panelists).

Source	n[3]	Overall like/dislike		Tenderness like/dislike		Flavor like/dislike		Juiciness like/dislike	
USDA Choice	27	6.7	±0.19^{ab}	7.3	±0.20^{ab}	6.5	±0.23^{ab}	5.7	±0.22^{b}
USDA Select	27	6.1	±0.19^{cd}	6.8	±0.20^{bcd}	6.0	±0.23^{b}	5.7	±0.22^{b}
White-Fat Cow	27	7.2	±0.19^{a}	7.4	±0.20^{a}	6.8	±0.23^{a}	7.2	±0.22^{a}
Yellow-Fat Cow	27	6.5	±0.19^{bc}	6.6	±0.20^{d}	6.2	±0.23^{ab}	6.8	±0.22^{a}
Australian	27	6.9	±0.19^{ab}	7.3	±0.20^{abc}	6.8	±0.23^{a}	6.8	±0.22^{a}
Uruguayan	27	5.6	±0.19^{d}	6.7	±0.20^{cd}	5.4	±0.23^{c}	6.1	±0.22^{b}
P value		< 0.0001		0.0105		< 0.0001		< 0.0001	

[a–d]Least squares means in the same column without common superscript letters differ ($P < 0.05$).

[1]Sensory panel ratings: overall like/dislike (9 = like extremely; 1 = dislike extremely), tenderness like/dislike (9 = like extremely; 1 = dislike extremely), flavor like/dislike (9 = like extremely; 1 = dislike extremely), and juiciness like/dislike (9 = like extremely; 1 = dislike extremely).

[2]Tenderloin sources: (1) USDA Choice (U.S. Department of Agriculture, 2017), (2) USDA Select (U.S. Department of Agriculture, 2017), (3) white-fat cow (industry term used to describe products primarily from dairy cows where high-concentrate feeding results in external fat that is generally white in appearance and carcasses are similar in quality to USDA Select or higher), (4) yellow-fat cow (industry term used to describe products primarily from beef cows where forage-based feeding results in external fat that is generally yellow in appearance and carcasses are similar to USDA Utility or USDA Cutter), (5) Uruguayan (imported products from the country of Uruguay where the cattle are primarily forage-finished), and (6) Australian (imported products from the country of Australia where the cattle are primarily forage-finished).

[3]Number of tenderloins.

tenderloins were sourced from cattle of dairy influence. Miller et al. (1983) found that trained panelists did not detect differences in tenderness and flavor of carcasses with different maturity, when marbling was held constant.

Although some US consumers think of Australian beef as being primarily grass-fed and having lower palatability scores (Garmyn et al., 2020), the tenderloins sourced for this project were from cattle that combined pasture feeding with grain finishing. This likely contributed to the overall liking of the Australian steaks. Additionally, the greater overall liking of Australian steaks could be due to the implementation of the Meat Standards Australia system, which was designed to provide consumers with a guaranteed quality eating experience (Bonny et al., 2018). For the Meat Standards Australian system, a variety of physical and chemical carcass factors are entered into the database, which then predicts palatability scores based on previous consumer panel data (Meat & Livestock Australia, 2011). This system also helps predict the palatability of different muscles in an effort to increase consumers' overall satisfaction with Australian beef products (Bonny et al., 2018).

USDA Choice steaks ranked higher ($P < 0.05$) in overall liking than USDA Select steaks, whereas yellow-fat cow steaks did not differ ($P > 0.05$) from either USDA Choice or USDA Select steaks. The results of this study for USDA Choice steaks and USDA Select steaks conflict with previous research by O'Quinn et al. (2015), who found that quality grades did not impact a consumer's perception of overall liking for tenderloins.

For consumer panel ratings, there were tenderness like/dislike differences ($P = 0.0105$) among sources (Table 2). White-fat cow steaks, USDA Choice steaks, and Australian steaks had similar ($P < 0.05$) consumer panel ratings for tenderness. Furthermore, the results of this study for white-fat cow steaks align with a study by Shorthose and Harris (1990), who found that there was no statistical difference in tenderness values of the M. psoas major regarding the age of the animal at slaughter. This would also help explain why there was no observed difference between the white-fat cow steaks and the USDA Choice steaks, even though there may have been a maturity difference.

Consumer panelists also identified differences ($P < 0.0001$) for flavor like/dislike among sources (Table 2). White-fat cow steaks, Australian steaks, USDA Choice steaks, and yellow-fat cow steaks had similar ($P > 0.05$) overall ratings for flavor liking, whereas Uruguayan steaks had the lowest ($P < 0.05$) rating. Flavor ratings for USDA Choice and USDA Select steaks did not differ ($P > 0.05$). In the current study, results for flavor among USDA quality grades align with research done by Legako et al. (2015), who reported that consumers ranked USDA Choice and USDA Select graded cuts to be similar in flavor from the M. psoas major. USDA quality grade data also align with O'Quinn et al. (2015), whose data showed that consumers' perception of flavor had no statistical difference among quality grades of USDA Choice and USDA Select in tenderloin steaks. Sitz et al. (2005) reported that the domestic product rated higher in flavor than the Australian beef. This contrasts with the results of the present study, which reported no statistical differences for flavor between these 2 groups. We assume that the low flavor like/dislike rating for the Uruguayan steaks could be due in part to the different feeding or management practices used on the Uruguayan cattle.

As shown in Table 2, consumers ranked white-fat cow steaks, yellow-fat cow steaks, and Australian steaks greatest ($P < 0.05$) for juiciness liking. In contrast, Uruguayan steaks, USDA Choice steaks, and USDA Select steaks were ranked lowest ($P < 0.05$). Although in this study chronological age of carcasses was unknown, Hoffman et al. (2020) reported that C-maturity carcasses tended to be rated as juicier by consumers when compared to B-maturity carcasses. Smith et al. (1982) also reported that as overall maturity increased, consumers' perception of juiciness also increased. It may be that the white-fat cow steaks, yellow-fat cow steaks, and Australian steaks were sourced from carcasses more advanced in maturity than the steaks sourced from USDA Choice, USDA Select, and Uruguayan carcasses. Liu et al. (2020) also reported that juiciness can be influenced by other palatability factors. Therefore, tenderness and flavor of the different groups could be influencing the perceived juiciness by the consumers. This would also align with O'Quinn et al. (2015), who stated that the "halo" effect caused by the high tenderness values could be influencing the higher juiciness values perceived by the consumers.

White-fat cow steaks, Australian steaks, and USDA Choice steaks were ranked greatest ($P < 0.05$) overall and received similar ratings for tenderness and flavor. When consumers were allowed to describe what they liked and/or did not like about these samples, the following qualitative terms most frequently used were "tender, juicy, and flavorful" (data not reported in tabular form). Uruguayan steaks received the lowest or among the lowest consumer sensory ratings, with

flavor like/dislike being most likely to have had the greatest impact on overall like/dislike ratings. When describing qualitative traits of Uruguayan steaks, consumers most frequently reported that they disliked the flavor, that the sample was dry, and that it had a sour taste (data not reported in tabular form).

WBS force evaluations

Least-squares means for WBS force values (N) for steaks from each carcass source can be found in Table 3. White-fat cow steaks, yellow-fat cow steaks, Australian steaks, and USDA Choice had similar ($P > 0.05$) WBS force values. In this study, WBS force values support findings from consumer sensory panel ratings. Generally, white-fat cows and Australian steaks were the most tender as measured by both the consumer sensory panel and WBS force testing. Caine et al. (2003) show that even though WBS force may be used to evaluate tenderness, in our study, it could not be relied upon entirely to predict consumers' perception of tenderness. Therefore, consumer panels should still be run in conjunction with WBS force tests to provide an accurate assessment of tenderness.

Table 3. Least squares means of Warner-Bratzler Shear (WBS) values stratified by tenderloin source.[1]

Source	n^2	WBS (N)
USDA Choice	27	16.45^{abc}
USDA Select	27	17.63^{ab}
White-Fat Cow	27	15.03^{c}
Yellow-Fat Cow	27	15.19^{c}
Australian	27	15.97^{bc}
Uruguayan	27	17.80^{a}
P value		0.0024
SEM[3]		±0.59

[a–d]Least squares means within a column lacking a common letter differ ($P < 0.05$).

[1]Tenderloin sources: (1) USDA Choice (U.S. Department of Agriculture, 2017), (2) USDA Select (U.S. Department of Agriculture, 2017), (3) white-fat cow (industry term used to describe products primarily from dairy cows where high-concentrate feeding results in external fat that is generally white in appearance and carcasses are similar in quality to USDA Select or higher), (4) yellow-fat cow (industry term used to describe products primarily from beef cows where forage-based feeding results in external fat that is generally yellow in appearance and carcasses are similar to USDA Utility or USDA Cutter), (5) Uruguayan (imported products from the country of Uruguay where the cattle are primarily forage-finished), and (6) Australian (imported products from the country of Australia where the cattle are primarily forage-finished).

[2]Number of tenderloins.

[3]SEM = standard error of the mean.

Cook yields

Table 4 reports the least-squares means for cook yields (%) of steaks destined for the consumer sensory panel and shear force analysis. White-fat cow steaks, USDA Select, and USDA Choice steaks had the greatest ($P < 0.05$) cook yields.

Conclusions

Tenderness has been and continues to be one of the driving factors in a consumer's satisfaction with beef products. This study identified potential alternative sources for tenderloin steaks that may be more cost-effective, without sacrificing consumer acceptability. The emphasis consumers place on tenderness resulted in tenderloins from white-fat cow carcasses ranking greatest among palatability traits across all 4 of the factors evaluated in this study. Consumers also found tenderloins from Australian cattle to be more palatable, or showed no differences when compared with USDA Choice tenderloins. White-fat cow and Australian carcasses could both serve as potential lower-cost sources of tenderloins for foodservice establishments, without sacrificing a consumer's eating experience.

Table 4. Least squares means for cook yields of consumer sensory and shear steaks stratified by source.[1]

Source	n^2	Cook yield (%)
USDA Choice	27	77.2^{a}
USDA Select	27	77.2^{a}
White-Fat Cow	27	77.7^{a}
Yellow-Fat Cow	27	74.8^{b}
Australian	27	73.8^{b}
Uruguayan	27	73.7^{b}
P value		< 0.0001
SEM[3]		±0.4

[a–c]Least squares means within a column lacking a common letter differ ($P < 0.05$).

[1]Tenderloin sources: (1) USDA Choice (U.S. Department of Agriculture, 2017), (2) USDA Select (U.S. Department of Agriculture, 2017), (3) white-fat cow (industry term used to describe products primarily from dairy cows where high-concentrate feeding results in external fat that is generally white in appearance and carcasses are similar in quality to USDA Select or higher), (4) yellow-fat cow (industry term used to describe products primarily from beef cows where forage-based feeding results in external fat that is generally yellow in appearance and carcasses are similar to USDA Utility or USDA Cutter), (5) Uruguayan (imported products from the country of Uruguay where the cattle are primarily forage-finished), and (6) Australian (imported products from the country of Australia where the cattle are primarily forage-finished).

[2]Number of tenderloins.

[3]SEM = standard error of the mean.

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Declaration of Competing Interest

There are no known conflicts of interest by any of the authors.

Author Contribution

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Jeffrey W. Savell: Conceptualization, Funding acquisition, Investigation, Supervision, Writing – review & editing.

Kerri B. Gehring: Conceptualization, Funding acquisition, Investigation, Project Administration, Writing – review & editing.

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