

## Organoleptic Factors Responsible for the Superior Palatability of Japanese Wagyu Beef

Akihiro Okitani

Department of Food Science and Technology, Nippon Veterinary and Animal Science University,  
Musashino-shi, Tokyo 180-8602, Japan

## ABSTRACT

We investigated the reason why Japanese prefer Wagyu beef from Japanese Black Cattle to imported beef.

Since some imported beef was tender enough to satisfy Japanese, the superiority of Wagyu beef was not ascribable to the difference in texture.

While there was no difference in taste between Wagyu beef and imported beef, the odor of Wagyu beef was evaluated to be more desirable than that of imported beef.

On the basis of our hypothesis that this desirable odor was induced by conditioning of beef, we performed some experiments and obtained the result that the conditioning of dairy steer beef (beef marbling grade was likely to be 3), improved the odor but not taste. The desirable odor was detected in both raw and cooked meats. Thus, we named the desirable odor of the raw meat, which was sweet and milk-like odor the conditioned raw beef aroma and examined its generation mechanism.

*Brochothrix thermosphacta* which was facultatively anaerobic and psychrophilic bacterium was demonstrated to produce this aroma at the site containing both leans and fats in the presence of oxygen.

The survey of commercial Wagyu beef revealed that some beef presented a strong desirable odor after heating in spite of its low count of *Brochothrix thermosphacta*. Since this sweet and fatty odor was shown to be different from the conditioned raw beef aroma, we named it the conditioned boiled beef aroma and examined its generation mechanism.

This aroma was generated at the site containing both leans and fats which was conditioned in the presence of oxygen and then heated at ca. 80°C. No microorganism was responsible for the generation of this aroma.

This aroma was produced effectively in the marbled and sliced beef conditioned in air. Therefore, when highly-marbled Wagyu beef is conditioned in air and then used for cooking such as sukiyaki and shabu-shabu in which the beef is boiled, it is evaluated to be markedly palatable because of the developed desirable odor, i.e., the conditioned boiled beef aroma. We concluded that the lean meat type of imported beef in our country was estimated to be less palatable than Wagyu beef because of the failure of this aroma.

## INTRODUCTION

For Japanese people beef is at the first preference among animal meats. Therefore, consumption of imported beef has increased year by year since the regulation of beef import was abolished. However, on the basis of the survey of consumer's preference imported beef was evaluated to be less desirable than domestic beef, especially Wagyu beef. Thus, we started to investigate the reason for the palatability of Wagyu beef.

Since the palatability perceived when beef is chewed in the oral cavity is composed of factors such as texture, taste and odor, we compared those factors between domestic beef and imported beef. The results allowed us to conclude that the palatability of Wagyu beef was mainly due to its abundance of a specific aroma pleasant to Japanese. We found that in-air conditioning of highly-marbled beef produced the conditioned raw beef aroma (sweet and milk-like odor) and the conditioned boiled beef aroma (sweet and fatty odor). The conditioned boiled beef aroma was demonstrated to be the main reason for the palatability of Wagyu beef.

In this paper we described the process of our research leading to this conclusion and findings so far about the generation mechanism of both aromas.

## CONSUMPTION OF BEEF AND CONSUMER'S PREFERENCE IN JAPAN

## 1. Consumption of beef in Japan

The amount of beef consumed in Japan in 1996 was about 1,450,000 t (cf. 2,200,000 t of pork and 1,800,000 t of chicken was consumed), which comprised 550,000 t of domestic beef and 900,000 t of imported beef<sup>1)</sup>.

Domestic beef is classified into Wagyu beef and others. Wagyu beef consists of the meats of Japanese Black Cattle, Japanese Brown Cattle, Japanese Shorthorn Cattle and Japanese Polled Cattle. Others include meats of dairy cattle, F<sub>1</sub> between dairy cattle and Wagyu beef cattle, etc. Imported beef consists of the meats of foreign beef cattle, e.g., Aberdeen Angus and Hereford.

About 90 % of Wagyu beef is the meat of Japanese Black Cattle which produce marbled meat most effectively.

Major cooking methods of beef in Japan are steak, roast, yakiniku (grilled with soy sauce), Hamburg steak, sukiyaki and shabu-shabu. Suki-yaki and shabu-shabu are Japanese original cuisines. In sukiyaki thin slices of beef are cooked with Welsh onion and a little amount of soy sauce. In shabu-shabu thin slices of beef are boiled in hot water for short time and served with seasoning sauce. Boiling of beef is the common character between both cuisines.

## 2. Japanese consumer's preference on beef

Japan Meat Information Service Center conducts a survey of consumer's preference through house wives of 2,000 families across the country every year. It showed that ca. 85 % of families always preferred domestic beef and only 3 % of families preferred

imported beef (Table 1)<sup>2</sup>. The major reason for the preference of domestic beef was "palatable" and that of imported beef was "cheap" (Table 2)<sup>2</sup>.

Table 1. Japanese consumer's preference for domestic beef and imported beef

Examination date	Number of families inquired	Rate (%) of families preferring			
		Domestic beef	Imported beef	Both	No answer
Dec. 1996	2,000	82.9	2.9	14.0	0.3
Jun. 1997	2,000	85.0	2.8	12.0	0.1
Dec. 1997	2,000	85.8	2.4	11.6	0.3
Jun. 1998	2,000	85.5	2.5	11.9	0.2

Table 2. Reason for choice of domestic beef or imported beef<sup>a</sup>

Reason <sup>b</sup>	Families preferring domestic beef <sup>c</sup> (%)	Families preferring imported beef <sup>d</sup> (%)
High palatability	67.9	24.0
High quality	62.4	12.0
Good appearance	1.1	0
Low price	0.8	92.0
Easiness to buy	6.3	30.0
Family's preference	21.5	0
Others	13.4	4.0
No answer	0.1	0

a: The examination was conducted in June, 1998.

b: Reasons were selected up to two and the shares of the selected reasons were expressed as %.

c: 1,709 families.

d: 50 families.

On the survey of beef taste as shown in Table 3<sup>2</sup>, 83 % of families answered that Wagyu beef was palatable and only 0.6 % of families answered that it was not palatable. About 3 % of families answered that imported beef was palatable and 35 % of families answered that it was not palatable. Furthermore, 27 % of families answered that domestic beef other than Wagyu beef was palatable. It is noteworthy that considerable amounts of dairy cattle beef palatable for Japanese people are on the market.

Table 3. Japanese consumer's judgement on taste of domestic beef and imported beef<sup>a</sup>

Beef	Number of families inquired	Rate (%) of families judging as			
		Good	Moderate	Not good	No answer
Domestic beef					
Wagyu beef	2,000	82.8	15.8	0.6	0.9
Others	2,000	27.4	68.0	2.5	2.2
Imported beef	2,000	3.4	55.8	35.1	5.8

a: The examination was conducted in June, 1998.

### ORGANOLEPTIC EVALUATION OF JAPANESE WAGYU BEEF AND IMPORTED BEEF

Consumers answered that they preferred Wagyu beef because of its good taste, as shown in Table 3. We thus wondered if the reason was correct and what was the character of the good taste. We carried out sensory evaluation on texture, taste and odor of Wagyu beef using trained panelists in our laboratory to solve these problems.

#### 1. Tenderness<sup>3</sup>

The sensory evaluation on texture of the frozen, chilled or aged beef imported from Australia demonstrated that there was no difference in texture among the three samples and all of them were sufficiently tender. The frozen beef, which had been conditioned thoroughly before freezing, was found to be as tender as the chilled and aged beef.

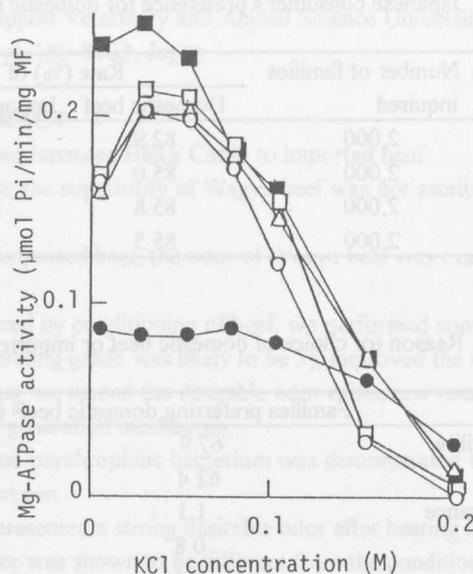
The fragmentation rates of myofibrils (showing the extent of weakening of Z-line, % of numbers of myofibrils composed of 1-4 sarcomeres to the sum of myofibrils) prepared by the homogenization of the three raw beef samples were the values as 70-80 %, which were almost equal to the values of those of dairy cattle beef samples tenderized sufficiently by conditioning.

The Mg-ATPase activity of myofibrils prepared from the three beef samples was as high as that of dairy cattle beef samples conditioned for 14 days (Fig. 1).

These results show that the failure in tenderness does not cause a lower palatability of imported beef than domestic beef.

Fig. 1. Mg-ATPase activities of myofibrils prepared from imported beef and domestic beef.

Myofibrils (MF) were prepared from chilled beef (○), frozen beef (△) and aged beef (□) imported from Australia in vacuum and domestic Holstein beef before (●) and after (■) 14 days-conditioning.



## 2. Taste and odor<sup>4)</sup>

Sensory evaluation was performed on the taste and odor between commercial Wagyu beef slices (from Japanese Black Cattle) and imported beef slices after boiling. The taste evaluation by the panelists with pinching their noses showed no significant difference between both samples (Table 4). On the other hand, when the panelists without pinching their noses evaluated samples, i.e., perceived taste and odor simultaneously, Wagyu beef was judged to be significantly more palatable than imported beef. These results indicated that Wagyu beef was evaluated to be palatable because of its superior odor, i.e., an aroma.

Table 4. Contribution of odor to palatability of cooked<sup>a</sup> Wagyu beef and cooked<sup>a</sup> imported beef

Experiment	Item	Number of samples judged to be preferable		Difference <sup>b</sup>
		Wagyu beef	Imported beef	
I	Taste <sup>c</sup>	5	3	NS
	Odor and taste <sup>d</sup>	8	0	**
II	Taste <sup>e</sup>	6	6	NS
	Odor and taste <sup>f</sup>	11	1	**

a: Beef samples (about 4 x 3 x 0.2–0.4 cm) was cooked in 1 % NaCl solution at 80°C for 2 min.

b: Significant difference was indicated with \*\* (P<0.01). NS, not significant.

c and e: evaluated by 4 or 6 panelists who pinched their noses, respectively.

d and f: evaluated by 4 or 6 panelists who did not pinch their noses, respectively.

## GENERATION OF AROMA IN BEEF BY CONDITIONING<sup>5,6)</sup>

Since we concluded that Wagyu beef was more palatable than imported beef because of its aroma, we tried to characterize the aroma.

We hypothesized that the aroma might be generated by conditioning and then performed experiments using dairy cattle beef to verify the hypothesis (Table 5). As a result, conditioning was found not to improve taste of heated beef but to improve its odor. The odor of beef before heating was also improved (Table 6). This orthonasal odor was named the conditioned raw beef aroma, which was sweet and milk-like odor. This aroma was recognized in some commercial Wagyu beef but was not in imported beef, suggesting that it was one of factors to bring the palatability to Wagyu beef.

Table 5. Contribution of odor to palatability of cooked beef loins from three head of dairy cattle (Holstein) after storage at 0° or -80°C

Item	Palatability	Numbers of judgements
Taste <sup>c</sup>	0°C-stored beef <sup>a</sup> > Frozen beef <sup>b</sup>	3
	0°C-stored beef <sup>a</sup> = Frozen beef <sup>b</sup>	19
	0°C-stored beef <sup>a</sup> < Frozen beef <sup>b</sup>	2
Odor and tasted <sup>d</sup>	0°C-stored beef <sup>a</sup> > Frozen beef <sup>b</sup>	14
	0°C-stored beef <sup>a</sup> = Frozen beef <sup>b</sup>	5
	0°C-stored beef <sup>a</sup> < Frozen beef <sup>b</sup>	5

a: stored in 0°C-air for 20 days after 4 days postmortem.

b: stored at -80°C for 18 days after 4 days postmortem and then thawed at 4°C for 2 days.

c: evaluated by 8 panelists who pinched their noses.

d: evaluated by 8 panelists who did not pinch their noses.

Table 6. Odor of raw beef loins from three head of dairy cattle (Holstein) after storage at 0°C or -80°C

Numbers of samples judged to be preferable		
0°C-stored beef <sup>a</sup>	Frozen beef <sup>b</sup>	Difference
22	2	***

Significant difference was indicated with \*\*\* (P < 0.001).

Odor evaluation was performed by 8 panelists.

a: stored in 0°C-air for 20 days after 4 days postmortem.

b: stored at -80°C for 18 days after 4 days postmortem and then thawed at 4°C for 2 days.

## CONDITIONS NECESSARY FOR THE GENERATION OF THE CONDITIONED RAW BEEF AROMA<sup>7)</sup>

### 1. Oxygen

Our investigation of the market demonstrated that all imported beef was conditioned as vacuum-packaged cut meat in order to suppress the growth of aerobic bacteria. In case of domestic beef, less-marbled beef was conditioned in vacuum-packaged, but highly-marbled beef (including some beef other than Wagyu beef) was conditioned as dressed carcasses or cut meat in air at 0-1°C for 10 days - a few months. Furthermore, in any case it was avoided to condition the highly-marbled Wagyu beef in vacuum.

Thus, we conditioned loins of the dairy cattle in air or vacuum at 0°C for 25 days. As a result, the conditioned raw beef aroma was generated in air but not in vacuum. Moreover, the experiment using an oxygen absorber showed that oxygen was essential for the formation of this aroma.

### 2. Coexistence of leans and fats

Loins of the dairy cattle were divided into three portions containing both leans and fats, leans alone and fats alone, respectively, and then stored in air, resulting in the more remarkable generation of this aroma in the portion containing both leans and fats than in the portions containing leans or fats alone.

This result suggested that the beef richer in contact faces between leans and fats, i.e., higher-marbled beef, was more advantageous for the generation of the aroma.

### 3. Bacteria

The generation of the aroma was markedly depressed in the beef which was sprayed with a chloramphenicol or a NaN<sub>3</sub> solution and then conditioned in air. This result suggested that some kind of bacteria but not yeasts or fungi produced the aroma at the site containing both leans and fats in the presence of oxygen. Thus, all bacterial isolates obtained from beef were inoculated into sterile lean extracts (sterilized with filters) floating sterile fats so that one bacterium producing the aroma was isolated.

This bacterium was a gram-positive bacillus and identified to be *Brochothrix thermosphacta* (BRT) by its features of the catalase test, the growth on the selective medium and others. BRT is a facultatively-anaerobic and psychrophilic bacterium occurring very often in commercial beef. It produces lactic acid but does not belong to a lactic acid bacteria. Although BRT is not putrefactive bacterium because of no production of amines, it is one of the bacteria to deteriorate meat quality, because sometimes it produces diacetyl and acetoin to give meat a sweaty odor. BRT has been observed to grow in both beef stored in air and vacuum.

BRT produced sweaty odor in the sterile lean extract, however the coexistence of beef fats allowed the generation of the aroma. This aroma became perceptible when the count of BRT reached 10<sup>7</sup>~10<sup>8</sup>/ml.

## DISCOVERY OF THE CONDITIONED BOILED BEEF AROMA AND CONDITIONS FOR ITS GENERATION<sup>4)</sup>

### 1. Difference between the conditioned boiled beef aroma and the conditioned raw beef aroma

On commercial beef slices, the strength of the conditioned raw beef aroma was evaluated before and after heating, and BRT was counted. Although in some samples the count of BRT was high and the aroma was strong, in some other samples the aroma was strong in spite of the low count of BRT. Some samples had the aroma more abundantly after heating than before heating.

The same investigation as above was carried out on Wagyu beef blocks conditioned for 1–2 months (Table 7). As a result, in the

Table 7. The strength of the conditioned raw beef aroma (CRBA) and the viable count of *Brochothrix thermosphacta* in conditioned Wagyu beef block

Sample	Portion	Strength of CRBA <sup>a</sup>		Viable count (count/g meat)
		Before heating	After heating <sup>b</sup>	
A	Upper surface	0.50	1.0	1.1 x 10 <sup>6</sup>
	Near-upper surface inside	0.50	1.3	4.8 x 10 <sup>2</sup>
	Core	0.25	0.67	0
	Near-lower surface inside	0.25	0.42	4.3 x 10 <sup>1</sup>
	Lower surface	0.42	0.75	6.5 x 10 <sup>4</sup>
B	Upper surface	0.35	0.90	3.0 x 10 <sup>5</sup>
	Near-upper surface inside	0.10	0.20	9.3 x 10 <sup>1</sup>
	Core	0	0.20	0
	Near-lower surface inside	0	0.10	0
	Lower surface	0.10	0.50	1.1 x 10 <sup>5</sup>

a: This shows average scores of the strength of CRBA evaluated by six (sample A) or five (sample B) panelists as follows: absent, 0; slight, 0.5; weak, 1.0; medium, 2.0; strong, 3.0.

b: The one side of beef samples (about 4 x 4 x 1 cm) was heated on a hot plate at 200°C for 1 min, and then the other side was heated for 30 sec.

surface portions of meat blocks the count of BRT was high and the aroma was also strong. However, some inside portions of meat blocks had the strong aroma in spite of a lower BRT count than 10<sup>3</sup>/g meat. In this case the aroma was stronger after heating than before heating.

These results allowed us to conceive the existence of another aroma, which was the retronasal aroma generated without BRT and perceived only after heating of beef. Reexamination of commercial marbled Wagyu beef and imported beef demonstrated that Wagyu beef had the strong aroma which was perceived well in boiled beef rather than roasted beef but not in raw beef and that imported beef did not have such aroma. This aroma is sweet and fatty odor. We propose to call this aroma the conditioned boiled beef aroma.

We concluded that this aroma was the main reason why Wagyu beef was recognized to be more palatable than imported beef in Japan.

### 2. Conditions necessary for the generation of the conditioned boiled beef aroma

We examined the optimum heating temperature for the generation of the conditioned boiled beef aroma. The strength of the aroma of commercial Wagyu beef slices cooked at 40, 60, 80 and 100°C was found to be ordered as: 80°C > 60°C > 40°C = 100°C.

Although this aroma was not detected in the highly-marbled beef block after 3 days postmortem, it was generated when the thin sliced was prepared from such beef block and then kept in 4°C-air for 5 days (Table 8). When beef blocks themselves were kept

Table 8. The conditioned boiled beef aroma (CBBA) of Wagyu beef at the highest grade of marbling stored additionally in air or vacuum and then cooked<sup>a</sup>

Storage period (day)	Panelist number	Numbers of samples judged to have stronger CBBA								
		Slice in 4°C-air	Block in -80°C-air <sup>b</sup>	No difference	Block in 4°C-air <sup>c</sup>	Block in -80°C-air <sup>b</sup>	No difference	Slice in 4°C-air	Slice in 4°C-vacuum	No difference
1	5 or 4	3	2	0	1	3	0	4	0	0
5	5	4	1	0	2	3	0	4	1	0
11	7	6	1	0	—	—	—	—	—	—

a: cooked in 1% NaCl solution at 80°C for 2 min.

b: After storage, a frozen block was thawed in tap water and sliced for cooking.

c: After storage, a block was sliced for cooking.

likewise, the aroma is generated more slowly than in the case of slices (Table 8). When thin slices of the above-mentioned beef was stored in air or vacuum at 4°C for 5 days, slices in air had the stronger aroma than slices in vacuum (Table 8).

When thin slices prepared from the less-marbled beef block after 5 days postmortem was kept in 4°C-air for 5 days, they did not have the stronger aroma than blocks kept at -80°C.

These results suggested that a considerable level of fat-marbling and oxygen were necessary for the generation of the aroma.

### CONCLUSION

The storage of the highly-marbled beef in air was demonstrated to induce the conditioned raw beef aroma and the conditioned boiled beef aroma. We concluded that the presence of the conditioned boiled beef aroma was the main reason why Japanese people evaluated that highly-marbled Wagyu beef was more palatable than less-marbled imported beef.

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