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Effect of modified atmosphere packaging on microbiology and shelf-life of dark cutting beef (#358)

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Introduction

Dark-cutting beef (high pHu beef) is generally unacceptable to the consumer due to its dark red color and limited shelf-life. These contribute to significant economic losses to the meat industry. High oxygen (HiOx, 80%O_2, 20%CO_2) and CO modified atmosphere packaging have already proven successfully to improve the color of dark-cutting beef steaks. However, these same packaging types may affect the microbial spoilage process of beef with different pHu. This relationship remains to be tested. Therefore, this study aimed to investigate the microbiology quality and shelf-life of dark-cutting beef under three packaging conditions. The results will provide information on whether dark-cutting beef is suitable for distribution as fresh meat under modified atmosphere packaging.

Methods

The M. *longissimus lumborum* (LL) were collected from 21 Simmental cattle (18 to 24 months old) in a commercial abattoir (24 h *post-mortem*). These were selected according to ultimate pH grouping: normal ultimate pH (pHu, 5.40-5.79, n=7), intermediate pHu (5.80-6.09, n=7) and high pHu (≥ 6.10, n=7). Vacuum packaged loins were transferred to the lab within 12 h. Each loin was cut into 7 equal ~ 2.54 cm beef steaks, which were randomly assigned to three packaging systems and three aging time (0, 7 and 14 d). The packaging types included vacuum packaging, HiOx-modified atmosphere packaging (MAP) and CO-MAP (0.4% CO/ 30% CO_2/ 69.6% N_2). Seven steaks representing each pHu group were sampled prior to packaging, being aging time 0 samples. Microbial counts (total viable counts (TVC), *Enterobacteriaceae*, lactic acid bacteria (LAB) and *B. thermosphacta*) and total volatile basic nitrogen (TVBN) were determined at each aging time. All data were analyzed using the MIXED procedure (SAS, Version 9.0) with pHu group, aging time, packaging type and their interactions were fitted as fixed effects; and animal was fitted as a random effect. Differences in Least squares means (LSM) for all traits were conducted using PDIFF option, and significant difference were considered when $P < 0.05$.

Results

There were no significant pHu × packaging type × storage time interactions for bacterial proliferation, but pHu and storage time interacted to affect the growth of TVC, *B.thermosphacta* and *Enterobacteriaceae* ($P < 0.05$, Table 1). TVC increased rapidly in dark-cutting beef and intermediate pHu beef, whilst progressively increased in normal pHu beef. Both dark-cutting and intermediate pHu beef had higher TVC than normal pHu beef ($P < 0.05$) on 14 day, reaching 7.75 log CFU/g and 7.26 log CFU/g, respectively. Significant differences were noted in *Enterobacteriaceae* counts among these treatments throughout day 7 to 14,in which dark-cutting beef showed the highest *Enterobacteriaceae* counts. Only aging time affected LAB counts ($P < 0.05$). A pronounced increase of LAB could be detected in all packaging types after the first aging time interval ($P < 0.05$), reaching 4.83 log CFU/g on day 14. Meanwhile from day 7,dark-cutting and intermediate pHu beef showed higher *B. thermosphacta* levels than normal pHu beef. Moreover, *B. thermosphacta* level was affected by packaging and aging time interaction effects ($P < 0.05$, Table 2). After the first week, the lowest population of *B. thermosphacta* were obtained in CO-MAP compared with that in VP and HiOx-MAP, which might attribute to antimicrobial properties of CO-MAP.

TVBN, as a direct quality indicator of meat deterioration and shelf life, and which is officiallly used in China, has been reported to be was positively correlated with the growth of spoilage bacteria. pHu and storage time interacted ($P < 0.05$) to impact beef TVBN (Table 3) as dark-cutting samples had highest TVBN increases across the aging time, reaching 16.27 mg/100g on day 14. This result suggests that the shelf-life of dark-cutting group was less than 14 days based on this trait (limit was ≤ 15 mg/100g).

Conclusion

This study reveals that pHu exerted more substantial effects on microbial growth and production of TVBN of chilled beef during aging, comparative to packaging type. Although CO-MAP exhibited the best preservative, demonstrated as *B. thermosphacta* growth inhibition, the packaging type can be said to not change the shelf-life of beef from each pHu group. Findings also suggested that the shelf-life of dark-cutting beef is less than 14 days, based on the TVBN values, indicating that dark-cutting beef is not suitable to sell as fresh cuts, either in the form of vacuum or MAPs.

Notes

Table 1 Effect of packaging and storage time on the microbial counts of beef steaks with normal, intermediate or high pHu (5.40-5.79; 5.80-6.09; ≥ 6.10) during chilled storage.

Colony counts (log CFU/g)	pH	Storage time (days)			Mean±SEM	*P*-value		
		0	7	14		pH	Storage time	pH×storage time
TVC	Normal	$4.21±0.24^{cx}$	$4.89±0.24^{by}$	$6.08±0.24^{ay}$	5.06±0.18	0.001	<0.001	<0.001
	Intermediate	$3.95±0.24^{cxy}$	$4.89±0.24^{by}$	$7.26±0.24^{ax}$	5.37±0.18			
	Dark-cutting	$3.61±0.24^{cy}$	$5.49±0.24^{bx}$	$7.75±0.24^{ax}$	5.62±0.18			
	Mean±SEM	3.92±0.18	5.09±0.18	7.03±0.18				
Enterobacteriaceae	Normal	$3.47±0.20^{abx}$	$3.18±0.20^{by}$	$3.73±0.20^{az}$	3.46±0.14	0.005	<0.001	<0.001
	Intermediate	$2.87±0.20^{by}$	$3.13±0.20^{by}$	$4.42±0.20^{ay}$	3.47±0.14			
	Dark-cutting	$2.64±0.20^{cy}$	$3.76±0.20^{bx}$	$5.16±0.20^{ax}$	3.86±0.14			
	Mean±SEM	2.99±0.14	3.36±0.14	4.45±0.14				
LAB	Normal	2.92±0.28	2.53±0.28	4.46±0.28	3.30±0.20	0.158	<0.001	0.137
	Intermediate	2.71±0.28	3.05±0.28	5.22±0.28	3.66±0.20			
	Dark-cutting	2.28±0.28	2.96±0.28	4.81±0.28	3.35±0.20			
	Mean±SEM	$2.64±0.20^{b}$	$2.85±0.20^{b}$	$4.83±0.20^{a}$				
B. thermosphacta	Normal	$0.96±0.31^{cx}$	$2.54±0.31^{bz}$	$4.46±0.31^{az}$	2.65±0.27	<0.001	<0.001	<0.001
	Intermediate	$1.36±0.31^{cx}$	$3.72±0.31^{by}$	$5.56±0.31^{ay}$	3.55±0.27			
	Dark-cutting	$1.24±0.31^{cx}$	$5.02±0.31^{bx}$	$6.58±0.31^{ax}$	4.28±0.27			
	Mean±SEM	1.19±0.27	3.76±0.27	5.53±0.27				

Table 1

$^{a-c}$ Means within the rows with different letters differ significantly (*P* < 0.05)$^{x-z}$ Means within the columns with different letters differ significantly (*P* < 0.05)

Table 2 *B. thermosphacta* counts of beef steaks packaged under different MAP conditions during chilled storage.

Trait	Packaging	Storage time (days)			*P*-value		
		0	7	14	Packaging	Storage time	Packaging×storage time
B. thermosphacta (log CFU/g)	VP	$1.19±0.31^{cx}$	$3.79±0.31^{by}$	$5.79±0.31^{ax}$	<0.001	<0.001	<0.001
	HiOx-MAP	$1.19±0.31^{cx}$	$4.50±0.31^{bx}$	$6.10±0.31^{ax}$			
	CO-MAP	$1.19±0.31^{cx}$	$2.99±0.31^{bz}$	$4.70±0.31^{ay}$			

Table 2

$^{a-c}$ Means within the rows with different letters differ significantly (*P* < 0.05) $^{x-z}$ Means within the columns with different letters differ significantly (*P* < 0.05)

Notes