คุณภาพเนื้อและคาร์บอนฟุตพริ้นท์ของเนื้อโคซูวีที่อุณหภูมิและระยะเวลาแตกต่างกัน

Meat quality and carbon footprint of sous vide cooked beef at different temperatures and times

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บทคัดย่อ: ซูวีเป็นวิธีการปรุงอาหารที่ควบคุมอุณหภูมิอย่างแม่นยำในถุงพลาสติกแพ็คด้วยสูญญากาศ การให้ความร้อนที่แม่นยำทำให้ได้ความสุกและเนื้อสัมผัสมากกว่าวิธีการทำอาหารแบบดั้งเดิม การวิจัยครั้งนี้ทำการศึกษาลักษณะทางเคมีกายภาพ คาร์บอนฟุตพริ้นท์และราคาของเนื้อสันนอกโคที่ผ่านการซูวีที่อุณหภูมิ (55, 59 และ 70 องศาเซลเซียส) และระยะเวลา (1, 6, 12, 24 และ 48 ชม.) ที่แตกต่างกัน ผลการศึกษาพบว่าอุณหภูมิและระยะเวลามีผลต่อค่าการสูญเสียน้ำออกจากเนื้อ (CL) ค่าแรงตัดเฉือนเนื้อ ค่า springiness ค่า cohesiveness ค่า gumminess และ ค่า chewiness การซูวีที่อุณหภูมิสูงทำให้ค่า CL ค่า ΔE ค่า firmness ค่า hardness ค่า springiness ค่าgumminess และ ค่า chewiness สูงขึ้น แต่ค่า L* ลดลง การเพิ่มระยะเวลามีผลต่อค่า CL ค่า L* ค่า a* ค่า b* ค่า h* ค่า browning index เนื้อสัมผัส คาร์บอนฟุตพริ้นท์และราคา การซูวีที่อุณหภูมิ 59 องศาเซลเซียส เวลาไม่เกิน 6 ชม. สามารถลดคาร์บอนฟุตพริ้นท์และราคาได้

คำสำคัญ: ซูวี, คุณภาพเนื้อ, คาร์บอนฟุตพริ้นท์, เนื้อโค

ABSTRACT: Sous vide is the cooking method at precisely controlled temperatures in vacuumed plastic pouches. Accurate heating offers more doneness and texture options than traditional cooking methods. This research examined the physicochemical characteristics, carbon footprint and cost of beef longissimus dorsi sous vide cooked at different temperatures (55, 59, and 70 °C) and times (1, 6, 12, 24 and 48 h). Results showed that cooking temperatures and times were significantly interacted in cooking loss (CL), work of shear/ toughness, springiness, cohesiveness, gumminess, chewiness, carbon footprint, and cost. Higher temperatures increased cooking loss, ΔE, firmness, hardness, springiness, gumminess, chewiness, carbon footprint, and cost; but, reduced L*. Prolonged cooking times affected on CL, L*, a*, b*, h*, browning index, and texture profiles, carbon footprint, and cost. Cooking at 59 °C for less than 6 can be reduced carbon footprint and total cost.

Keywords: sous vide, meat quality, carbon footprint, beef

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Introduction

Sous vide or "under vacuum" defines a cooking technique of food at precisely controlled temperatures avoiding over- or undercooking in food-grade plastic sealed vacuum pouches. It is well-known that this cooking has several benefits: keeping palatability, holding nutrients, and eliminating the microbial risk (Baldwin, 2012). The long cooking times has been used since earliest times to make tough meat cuts more appetizing. In fact, by melting collagen into gelatin, this cooking can twice increase tenderness of the meat and reducing among myofibrillar intercross linkages (Davey et al., 1976). At lower temperatures, when cooked between 55–60°C for several hours to numerous days, tough cutting of beef (Bouton and Harris, 1981) was the most tender. However, it is applicable to assess if meat from diverse categories having a differences in structure of connective tissue, requires different treatments in order to be tendered. The carbon footprint of food is the greenhouse gas (GHGs) emissions starting from growing or raising to disposal. The carbon foot print has found much more in animal than crop produces (Environmental Working Group, 2011). There is little information about carbon footprint production as making food using sous vide method. For this reason, the aim of this study was to assess meat quality and carbon footprint of beef from crossbred cattle using different temperatures and times of sous vide cooking.

Materials and methods

Bovine longissimus dorsi (LD) muscles from four crossbred Brahman × Thai native beef cow with 4 years of age were purchased from Amnat Charoen province's local market. The muscles were trimmed and a total of 15 parts were then cut with the 1-inch-thick steak. The samples weight and color were measured prior to study. The samples were then randomly divided into three sous vide cooking temperatures at 55, 59, and 70°C and five prolong times including 1, 6, 12, 24, and 48 h, respectively. All samples were packed in LLDPE vacuum bag (15×17 cm) and cooked using an immersion cooker (SVJ-1000, Sous Vide Precision Cooker, China). The cooking steps proceeded follow: (1) preparing the beef, (2) vacuum the bag, (3) heating the beef, (4) finishing, (5) and analyzing. All removed samples were kept under room temperature until cold prior to further analysis for cooking loss, surface color (CR-400, Minolta Co. Ltd., Osaka, Japan), total color difference ($\Delta E = [(L1^* - L2^*)2 + (a1^* - a2^*)2 + (b1^* - b2^*)2]1/2$) (AMSA, 2012) and browning index ($B.I. = [100 (x - 0.31)]/ 0.17)$), where: $x = (a^* + 1.75L^*)/ (5.645L^* + a^* - 3.012b^*)$ (Mohammadi et al., 2008).

Firmness and work of shear/ toughness analysis was based on AMSA guidelines (AMSA, 2012). Lastly, texture profile analysis (TPA) as described by Bourne (1978) was evaluated using the TA-XT. plus Texture Analyzer (Stable Micro System Ltd., Surry, UK) equipped with an aluminum cylindrical probe P/50. Six samples from the steaks were cut into 1x1.5x1 in parallel diameter to the longitudinal of the muscle fibers. The setting conditions were: test speed: 5.0 mm/s, strain: 75%, time: 5.0 s, trigger type: auto; trigger force: 5 g, and 50 kg of load cell. In each sample, the compressing 75% was performed in two cycles to determine hardness (kg), cohesiveness, springiness

(cm), gumminess (kg), and chewiness (kg).

Carbon footprint and total cost were calculated from the equation follows:

Carbon footprint (kgCO2e) = [(Beef (kg) × 9.912 kgCO2e) + (electricity use (kWh) × 0.6933 kgCO2e) + (plastic use (kg) × 2.0015 kgCO2e) + (tab water use (L) × 0.3238 kgCO2e]

where the emission factor obtained from report of Thai LCI/ MTEC (2016)

Total cost (Baht) = Beef price (280 Baht/kg) + Electricity bill (5 Baht/kWh) + plastic bill (130 Baht/kg) + water bill (16 Baht/m3)

Statistical analysis: All experimental records obtained from meat quality, carbon footprint and total cost were subjected to ANOVA for 3 × 5 factorial arrangements in CRD with three cooking temperatures (55, 59, and 70°C) and five cooking times (1, 6, 12, 24, and 48 h) using the GLM procedure (SAS, 2015). The differences at the 5% significant level among the means of each groups were compared by Duncan's New Multiple Range Test (Steel et al., 1997).

Results and discussion

The results of sous vide cooked beef on cooking loss, meat color, and browning index is shown in Table 1

Higher values in cooking loss were found when cooked at 70°C and longer time from 6 to 48 h compared to other treatments. This effect was reliable with the results of beef (García - Segovia et al., 2007). Cooking at 55 or 59°C for 1-12 h had the greater L* values. The indices of a*, b*, h*, and browning index did not affect by temperatures, but they were significantly increased with times except for a* values. Cooked meat color generally suggested higher L* and b*, whereas lower a* as temperature and cooking time increases. In current research, the lowest L* values found in samples cooked at 70°C and lengthier time because the sample seemed to more brown surface linking to more brown index as well. The ΔE was influenced by only temperature and presented the highest value when cooked at 59°C.

In Table 2, regarding shear values, the higher cooking temperatures, the greater firmness (peak force) presented. Increased work of shear/ toughness was seen when cooked at 59°C for 24 and 48 h. Though, Christensen et al. (2013) noted that prolonged cooking time at temperatures 53-63°C for up to 20 h in sous vide could reduce toughness in beef; however, in our study prolonged times did not affect any firmness. This result was consistent with 60 – 70°C cooked beef and goat meat (Ismail et al., 2019). For TPA, the springiness, cohesiveness, gumminess, and chewiness values were affected by combinations of temperatures and cooking times. These values showed the lowest in beef cooked at 70° C for 48 h compared to other combinations. The maximum temperature (70°C) resulted in harder meat, the softer meat was presented at 48 h. This may be explained by the higher degree of unfolding and denaturation of sarcoplasma proteins and myosin, and other collagen solubilization (Tornberg, 2005).

Sous vide cooked beef's emission footprint and cost were the highest values when treated at higher temperatures and longer times. In beef cooked at 70°C for 48 h had 17.11 kgCO2e and 125.46 Baht greater than those samples cooked lower heats or shorter times. Taking into 55 and 59°C cooking account, the longest time also generated higher CO2e releases and cost compared to the others. The values of

CO_2e quite high when compared to traditional meat cooking reported by Chester (2018), who found that gas emissions from electric roasted was 3.4926 $kgCO_2e$; however, charcoaled-grill turkey and smoked turkey required 17.4633 and 41.1861 $kgCO_2e$.

In conclusion, cooking at 70°C had the greatest values of cooking loss, firmness, and hardness. Prolonged times reduced a*, and some textural profiles; but, increased b* h* and cooking loss, and browning index. The most tender meat presented in sample cooked at 55°C and delayed time to 48 h. We suggested that cooking at 59°C for 1 to 6 h has a lowered carbon footprint and total cost.

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Table 1 Cooking loss, meat color, and browning index (mean ± SEM) of beef sous vide cooked at different temperatures and times.

Items	Cooking loss (%)	L*	a*	b*	C*	h*	ΔE	Browning index
Temperature (A)								
55 °C	14.41±1.02^{c}	48.35±0.97^{a}	11.99±1.03	17.10±0.75	21.30±0.62	55.20±2.95	14.80±0.87^{b}	61.76±2.38
59 °C	18.87±1.43^{b}	48.14±1.10^{a}	11.32±1.13	17.58±0.66	19.24±2.37	54.41±3.83	21.20±0.71^{a}	62.66±2.74
70 °C	30.88±2.57^{a}	44.47±0.99^{b}	9.90±0.84	17.34±0.47	20.19±0.54	60.63±2.17	17.12±2.70^{b}	65.71±2.42
Cooking time (B)								
1-h	13.47±1.50^{c}	50.69±1.03^{a}	15.56±1.39^{a}	15.12±0.48^{c}	22.15±0.82	45.52±3.39^{c}	20.46±1.14	57.67±1.30^{b}
6-h	20.46±2.29^{b}	47.97±1.07^{ab}	12.52±0.56^{b}	16.57±0.45^{bc}	20.90±0.34	52.95±1.73^{bc}	16.42±1.07	57.81±0.82^{b}
12-h	21.32±2.66^{b}	45.49±1.03^{b}	8.61±0.39^{c}	17.01±0.37^{b}	15.65±2.76	57.54±3.85^{ab}	17.21±0.87	57.15±1.32^{b}
24-h	24.58±2.40^{ab}	45.53±0.97^{b}	9.48±0.58^{c}	18.16±0.56^{ab}	20.61±0.51	62.41±1.78^{ab}	17.11±0.91	68.94±2.21^{a}
48-h	27.09±2.62^{a}	45.26±0.91^{b}	9.17±0.52^{c}	19.84±0.58^{a}	21.90±0.68	60.63±0.98^{a}	17.33±0.95	75.30±2.16^{a}
P-value								
A	<0.001	0.006	0.149	0.767	0.565	0.159	<0.001	0.285
B	<0.001	0.008	<0.001	<0.001	0.081	<0.001	0.053	<0.001
A*B	0.003	0.432	0.480	0.129	0.385	0.217	0.959	0.999

^{a,b,c} Different letters in column indicate significantly different (P<0.05)

Table 2 Meat texture, carbon footprint, and total cost (mean ± SEM) of beef sous vide cooked at different temperatures and times.

Items	Shear values		Texture profile analysis					Carbon footprint ($kgCO_2e$)	Total Cost (Baht)
	Firmness (kg)	Work of shear/ Toughness (kg.sec)	Hardness (kg)	Springiness (cm)	Cohesiveness	Gumminess (kg)	Chewiness (kg)		
Temperature (A)									
55 °C	5.58±0.43^{b}	43.65±3.00^{b}	5.66±0.34^{b}	0.21±0.01^{b}	0.54±0.02	3.02±0.19^{b}	0.63±0.06^{b}	5.99±0.52^{b}	63.08±3.13^{b}
59 °C	6.61±0.41^{ab}	55.56±1.92^{a}	6.86±0.56^{ab}	0.23±0.01^{a}	0.50±0.01	3.44±0.29^{ab}	0.79±0.08^{ab}	6.15±0.62^{b}	58.81±4.99^{b}
70 °C	7.13±0.33^{a}	43.65±3.05^{b}	7.64±0.70^{a}	0.23±0.01^{a}	0.52±0.01	4.02±0.42^{a}	0.96±0.11^{a}	8.96±1.24^{a}	79.53±7.61^{a}
Cooking time (B)									
1-h	5.82±0.49	45.51±3.80	8.17±0.76^{a}	0.21±0.01^{bc}	0.51±0.02	4.21±0.46^{a}	0.93±0.12^{a}	4.21±0.12^{e}	50.04±2.99^{c}
6-h	6.18±0.49	48.75±2.86	6.80±0.54^{a}	0.23±0.01^{a}	0.54±0.01	3.64±0.29^{a}	0.87±0.09^{a}	4.67±0.13^{d}	52.57±2.44^{c}
12-h	6.48±0.49	51.11±2.30	6.99±0.44^{a}	0.24±0.01^{a}	0.52±0.01	3.58±0.21^{a}	0.85±0.07^{a}	5.81±0.27^{c}	56.79±2.17^{c}
24-h	7.27±0.24	49.93±2.68	7.23±0.37^{a}	0.22±0.01^{ab}	0.53±0.01	3.81±0.20^{a}	0.88±0.07^{a}	8.27±0.50^{b}	76.85±3.58^{b}
48-h	6.44±0.32	49.18±3.38	4.41±0.26^{b}	0.20±0.00^{c}	0.50±0.01	2.23±0.18^{b}	0.45±0.05^{b}	12.21±0.95^{a}	99.46±5.33^{a}
P-value									
A	0.017	0.001	0.012	<0.001	0.138	0.019	0.002	<0.001	<0.001
B	0.295	0.670	0.001	<0.001	0.567	0.001	<0.001	<0.001	<0.001
A*B	0.152	<0.001	0.185	<0.001	0.015	0.030	0.002	<0.001	0.006

^{a,b} Different letters in column indicate significantly different (P<0.05).