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IMPACTO DA TEMPERATURA FINAL INTERNA EM DIFERENTES PROCESSOS DE TRANSFERÊNCIA DE CALOR NO PERFIL SENSORIAL DE CONTRAFILÉ BOVINO

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Thesis presented to the Faculty of Food Engineering of University of Campinas in partial fulfillment of the requirements for the degree of the Ph.D in Food and Nutrition, in Concentration area of Food Intake and Quality.

Tese apresentada à Faculdade de Engenharia de Alimentos da Universidade Estadual de Campinas como parte dos requisitos exigidos para a obtenção do título de Doutora em Alimentos e Nutrição, na Àrea de concentração de Consumo e Qualidade de Alimentos.

Orientadora: Prof(a).Dr(a). Helena Maria André Bolini

Este exemplar corresponde à versão final da tese defendida pela Carolina Lugnani Gomes e orientada pelo Prof. (a) Dr(a) Helena Maria Andre Bolini.

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SUMMARY

Two cooking methods (oven and griddles) and three end-point temperatures (65, 71 and 77°C) were applied in beef strip loin (m. *longissimus lumborum*), to assess which of the procedures provides a product with superior descriptive sensory profile in order to the sensory quality. Strip loin samples with the similar degree of fat thickness from the 12th rib to the second lumbar vertebra of the left side of the carcass of similarly age Angus steers were collected and frozen (-20ºC). Each piece was cut into six 2.54 cm thick steaks. The steaks remained vacuum packed and frozen. For cooking, the steaks were thawed at 4°C for 24 hours. The internal temperatures were monitored by thermocouples inserted in the geometric center of each steak. The interaction between cooking method and end-point temperature had a significant (P=0.002) impact on cooking loss. The increasing end-point temperature, constantly increase levels of cooking loss in both cooking methods, from 65ºC to 77ºC. At 65ºC and 71ºC the cooking loss were similar between oven and griddle, while at 77ºC the oven had the great loss, probably due to the long cooking. The interaction between cooking method and end-point temperature did not significantly impact (P=0.54) shear force. The steaks prepared at 65°C and 71ºC had lower (P<0.05) shear force values, while those prepared at 77°C had higher values (P<0.05). In acceptance analysis of appearance, aroma and flavor, samples cooked in electric oven, at higher temperatures, had the greater acceptance, however the tenderness and juiciness had greater acceptance in samples prepared at lower temperatures, regardless the method of cooking.

Steaks grilled on the counter-top griddles at 65°C yielded a sample with a significantly greater acceptability in terms of all of the sensory characteristics analyzed. For Descriptive Quantitative Analysis, steaks prepared in oven and griddles at 65°C were characterized by a blood aroma and flavor, a metallic flavor, juiciness, initial tenderness, apparent juiciness and internal red color. In the time-intensity analysis, the *Imax* values for tenderness and juiciness stimuli was higher ($P<0.05$) for the samples subjected to the electric oven as compared to the electric griddles. Regarding the temperatures, although the *Imax* for tenderness and juiciness of the samples subjected to temperatures of 65 and 71ºC were not different ($P>0.05$), it differed ($P<0.05$) from the samples at 77ºC. The *Ttot* value was not different ($P>0.05$) for both cooking methods and end-point temperatures in relation to the stimuli tenderness and juiciness. It can be suggested that the differences on tenderness and juiciness found by the assessors were noted only at first bite (*Imax*). Perception of tenderness and juiciness during chewing to swallowing (*Ttot*) did not vary, indicating that the samples remained homogeneous for both attributes after the first bite.

Keywords: **Beef strip loin, end-point temperature, cooking method, quantitative descriptive analysis, acceptance test, time-intensity analysis**

RESUMO

Dois métodos de cocção (forno e chapa) e três temperaturas internas finais (65, 71 e 77°C) foram aplicados em contrafilé bovino (m. *longissimus lumborum*), com o objetivo de avaliar qual dos procedimentos proporciona a obtenção de um produto com perfil sensorial descritivo superior em relação à qualidade sensorial. As amostras de contrafilé, porção compreendida da 12ª costela e a 2ª vértebra lombar, de meias carcaças esquerdas de bovinos da raça Angus, da mesma idade e acabamento de gordura, foram coletadas e congeladas (-20ºC). Cada peça foi cortada em seis bifes de 2.54 cm, que foram embalados a vácuo e mantidos congelados. Os bifes foram distribuídos em seis tratamentos. Para a cocção, os bifes foram descongelados a 4°C por 24 horas antes das análises. As temperaturas internas foram monitoradas por meio de termopares inseridos no centro geométrico de cada bife. Para a perda de peso por cocção, houve interação significativa do método de cocção X temperatura interna final (p=0.002). O aumento da temperatura aumentou constantemente as perdas por cocção em ambos os métodos de cocção, de 65ºC para 77ºC. A 65ºC e 71ºC as perdas por cocção foram similares entre forno e chapa, enquanto a 77ºC, as amostras assadas no forno tiveram as maiores perdas, provavelmente devido ao longo tempo de preparo. Para a força de cisalhamento, não houve interação do método de cocção X temperatura interna final (p=0.54). Os bifes preparados a 65°C e 71ºC tiveram menores valores de WBSF (p<0,05), enquanto que aqueles preparados a 77°C tiveram valores maiores (p<0,05). Na análise de aceitação, a aparência, o aroma e o sabor tiveram maior aceitação nas amostras preparadas no forno elétrico em temperaturas mais altas, entretanto a maciez e a suculência tiveram maior aceitação nas amostras preparadas em temperaturas mais baixas, independente do método de cocção. Os bifes grelhados na chapa elétrica a 65°C foram melhores, porque proporcionaram a obtenção de uma amostra com aceitação significativamente superior em relação a todas as características sensoriais analisadas. Na Análise Descritiva Quantitativa, os bifes do forno e da chapa a 65°C foram caracterizados pelos atributos de aroma e sabor de sangue, sabor metálico, suculência, maciez, suculência aparente e cor interna vermelha. Na análise tempo-intensidade, a *Imáx* do estímulo maciez e suculência foi significativamente maior ($p<0,05$) no forno elétrico em relação à chapa elétrica. E em relação às temperaturas a *Imáx* das amostras submetidas a 65 e 71ºC não diferiram ($p>0,05$), mas diferiram ($p<0,05$) das amostras a 77ºC. O *Ttot* não foi diferente ($p>0,05$) para as amostras nos métodos de cocção e nas temperaturas internas finais para os estímulos de maciez e suculência. Portanto sugere-se que as diferenças encontradas pelos assessores na maciez e suculência das amostras, foram percebidas somente a primeira mordida (*Imáx*). E durante a mastigação até a fase de deglutição (*Ttot*) não variaram, indicando que as amostras permaneceram igualmente homogêneas em relação aos dois atributos após a primeira mordida.

Palavras-chave: **Bife de contrafilé bovino, temperatura interna final, métodos de cozimento, análise descritiva quantitativa, análise de aceitação, análise tempo intensidade**

ÍNDICE

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1. INTRODUÇÃO GERAL

O Brasil é o segundo maior produtor de carne bovina e ocupa o primeiro lugar no quesito exportação, possuindo o segundo maior rebanho comercial do mundo, com aproximadamente 200 milhões de cabeças de gado (USDA, 2013). No período de janeiro a dezembro de 2013 foram abatidos 26,56 milhões de bovinos no Brasil em matadouros com inspeção federal, estadual ou municipal (ABIEC, 2013).

Entre os principais consumidores mundiais de carne bovina, o Brasil ocupa o segundo lugar e só perde para os Estados Unidos (USDA, 2013). No mundo, a bovina é a terceira carne mais consumida. No Brasil, seu consumo só perde espaço para carne de frango (FAO, 2012). Em 2013, o consumo *per capita* foi de 41 kg/ano para a carne bovina e 41,8 kg/ano para a carne de aves (ABIEC, 2013). Fonseca e Salay (2008) entrevistaram 351 consumidores de carne em Campinas, Estado de São Paulo. Destes, 95,7 e 97,4% consomem a carne bovina e a carne de frango, respectivamente, enquanto que a carne suína é consumida por apenas 68,9% dos entrevistados.

O contrafilé bovino (m. *Longissimus dorsi*) é o corte de preferência a ser analisado na maioria dos trabalhos (WHEELER, SHACKELFORD e KOOHMARAIE, 1999; OTREMBA et al., 2000; LAWRENCE et al., 2001; PEACHEY et al., 2002; MCKENNA, KING e SAVELL, 2003; OBUZ et al., 2004; DESTEFANIS et al., 2008; SASAKI et al., 2010; YANCEY, WHARTON e APPLE, 2011) sendo considerado um corte representativo das carnes para assar, fritar ou grelhar (FELICIO, 1999), além da facilidade em adquirir porções semelhantes em peso e tamanho.

De acordo com Schmidt et al. (2010) e Sasaki et al. (2010), não existe um bom nível de informações para o consumidor quanto à forma de preparo dos cortes cárneos, qual seja, fundamentalmente, o método e a temperatura interna final de cocção mais adequado para os cortes cárneos (GARCIA-SEGOVIA, BELLO e MONZÓ, 2007). Como o consumidor é o elo final da cadeia produtiva, sua opinião é importante para o estabelecimento das demandas ao longo de toda a cadeia (JEREMIAH e GIBSON, 2003; MCKENNA et al., 2004).

Segundo Shackelford, Wheeler e Koohmaraie (1995) a satisfação do consumidor de carne depende da combinação de três atributos de qualidade: sabor, suculência e maciez; sendo a maciez o atributo que mais influencia a aceitação pelos consumidores (SASAKI et al., 2010).

O consumidor tem interesse por métodos de cocção convenientes, mas que ofereçam um nível de palatabilidade aceitável na carne (JEREMIAH e GIBSON, 2003). A preferência dos consumidores por procedimentos mais simples e rápidos de cocção têm incentivado o desenvolvimento de novos equipamentos, que são comumente usados em residências pelos consumidores (MCKENNA, KING e SAVELL, 2003). Segundo Yancey, Wharton e Apple (2011), quando o método é semelhante ao que os consumidores utilizam em suas residências pode reduzir possíveis variações entre as avaliações subjetivas e objetivas de maciez na carne.

A aceitação de consumidores e a descrição completa dos atributos sensoriais percebidos em amostras de carne bovina, submetidas a diferentes métodos de cocção com temperaturas internas finais, já foram realizadas (WHEELER, SHACKELFORD e KOOHMARAIE, 1998; NEELY et al., 1999; OTREMBA et al., 2000; MCKENNA et al., 2004; LORENZEN et al., 2005; SCHMIDT et al., 2010).

No entanto, não existem registros em literatura científica de estudos do perfil sensorial de maciez, sabor e suculência de carne bovina durante o tempo de seu consumo com aplicação da técnica de análise sensorial dinâmica denominada tempo-intensidade, especialmente com as amostras preparadas em diferentes métodos de cocção e com diferentes temperaturas internas.

Os únicos registros encontrados foram publicados por Butler et al. (1996) que aplicaram análise tempo-intensidade para determinar o perfil sensorial de maciez em carne suína assada, Zimoch e Gullet (1996), que aplicaram a mesma técnica para analisar a suculência e a maciez de carne bovina assada em uma única temperatura interna. E Brown, Gérault e Walkeling (1996) que analisaram maciez e suculência de filés de carne bovina e suína.

A maciez e a suculência diminuem à medida que aumenta a temperatura interna. Os provadores não encontraram diferenças ($p>0.05$) entre as temperaturas de 71 e 77°C, mas diferenciaram ($p<0.05$) as amostras assadas a 60°C (LORENZEN et al., 2005, SASAKI et al., 2010; SCHMIDT et al., 2010; YANCEY, WHARTON e APPLE, 2011). Por este motivo, é interessante analisar se um determinado atributo varia ao longo do tempo de consumo em amostras submetidas a diferentes temperaturas internas finais.

A textura, especialmente a maciez, é uma característica sensorial importante, que varia durante a mastigação. A percepção deste atributo não ocorre apenas na primeira mordida, mas continua durante a fase de mastigação até a fase de deglutição (BUTLER et al., 1996). Portanto, a análise da modificação do perfil da maciez durante esse período é de extrema importância e o registro com quantificação contínua das variações de maciez podem ser realizadas unicamente com aplicação da análise tempo-intensidade computadorizada.

A determinação do perfil tempo-intensidade de maciez, suculência e sabor em amostras de carne bovina submetidas à cocção em diferentes condições, pode trazer informações inéditas e importantes para a área de pesquisa em alimentos, que podem contribuir para melhoria e escolha de condições adequadas para proporcionar a obtenção de um produto com adequações e características de textura, de acordo com as preferências dos consumidores.

2. OBJETIVO

Dois métodos de cocção (forno e chapa elétrica) com três temperaturas internas finais (65, 71 e 77°C) foram aplicados em contrafilé bovino (m. *longissimus lumborum*) com o objetivo de avaliar quais procedimentos proporcionam a obtenção de uma carne com perfil sensorial descritivo superior em relação à qualidade sensorial.

Objetivos específicos

- Determinar o perfil sensorial descritivo das amostras por meio da Análise Descritiva Quantitativa (ADQ).
- Determinar a aceitação sensorial com consumidores de bifes de contrafilé bovino.
- Determinar por análise estatística multivariada quais os termos descritores que contribuem positivamente e aqueles que contribuem negativamente para a aceitação do contrafilé assado e grelhado, de acordo com a preferência do consumidor.
- Determinar os perfis das curvas tempo-intensidade das amostras de carne bovina em relação aos estímulos de maciez e suculência.
- Determinar a aceitação e preferências de consumidores e a classificação de termos descritores do perfil sensorial descritivo por ordem de importância na discriminação de bifes de contrafilé bovino.
- Determinar a perda de peso por cocção e a força de cisalhamento das amostras de contrafilé bovino.

3. REVISÃO BIBLIOGRÁFICA

3.1. Características de Textura

A percepção de impressões visuais, olfativas e gustativas que se tem do alimento preparado por qualquer um dos processos usuais de cozimento é extremamente importante, sendo característico para cada corte comercial (FELICIO, 1999). A palatabilidade da carne compreende os atributos de aparência, maciez, suculência, sabor e aroma (HEDRICK et al., 1994).

A textura dos alimentos é um atributo sensorial que possui os atributos primários: maciez, coesividade, viscosidade, elasticidade e adesividade; secundários como: gomosidade, mastigabilidade, suculência, fraturabilidade; e residuais como: velocidade de quebra, absorção de umidade e sensação de frio na boca (CIVILLE e SZCZESNIAK, 1973). Os atributos mais importantes para a textura da carne são a maciez e a suculência (ZIMOCH e GULLETT, 1996; BUTLER et al., 1996; OBUZ et al., 2004; WALSH et al., 2010).

A maciez é o fator mais importante para o consumidor, para julgar a qualidade da carne (BUTLER et al., 1996). A maciez da carne cozida é a força requerida para compressão de uma substância entre os dentes molares (para sólidos) ou entre a língua e o palato (para semi-sólido) (CIVILLE e SZCZESNIAK, 1973). Uma força maior para o cisalhamento indica maior dureza da carne. Durante o aquecimento até 50-60ºC ocorre um aumento da força de cisalhamento. A 65ºC ocorre uma queda brusca desta força, que aumenta novamente até chegar aos 80ºC (Tornberg, 2005).

As correlações de medidas de força de cisalhamento com análise sensorial de maciez de carne são bastante variáveis, com valores de r variando de -0,32 a -0,94 (CAINE et al., 2003; DESTEFANIS et al., 2008). Esta variabilidade depende de vários fatores, tipo de músculo, preparação da amostra, método de cocção, o equipamento e procedimento de cisalhamento e o tipo de treinamento realizado com os provadores (DESTEFANIS et al., 2008).

A suculência da carne cozida é a sensação de umidade percebida nos primeiros movimentos de mastigação, devido à rápida liberação de líquido pela carne e, também, da sensação de suculência mantida, devido principalmente à gordura que estimula a salivação (ZIMOCH e GULLETT, 1996). A gordura intramuscular aumenta a sensação de suculência na carne. A suculência da carne depende também da perda de água durante o cozimento. Temperaturas de 80ºC produzem maiores perdas no cozimento que temperaturas ao redor de 60ºC (OTREMBA et al., 2000).

3.2. Análise Sensorial

A Análise Sensorial é usada para evocar, medir, analisar e interpretar reações às características dos alimentos e materiais como são percebidas pelos sentidos da visão, olfato, gosto, tato e audição (ABNT, 1993).

Avaliar um produto sensorialmente faz parte do cotidiano do ser humano, que o fazem naturalmente desde crianças, quando aceitam ou rejeitam um alimento ou ainda quando preferem um produto em relação a outro (FERREIRA et al., 2000).

Diferentes tipos de testes sensoriais podem ser aplicados de acordo com a informação que se deseja obter. Se o objetivo é descobrir o grau de aceitação ou preferência de um produto em relação a outro, testes afetivos devem ser conduzidos com a população consumidora do produto. Para saber se existe diferença entre duas amostras, testes discriminativos devem ser conduzidos. E ainda, se o objetivo é descobrir se existem diferenças significativas entre duas ou mais amostras, quais são elas e qual a sua ordem de grandeza, testes descritivos devem ser realizados com uma equipe de provadores treinados (STONE, BLEIBAUM e THOMAS, 2012).

3.2.1. Análise Descritiva Quantitativa

A qualidade sensorial de um alimento é composta de vários atributos, que são percebidos individualmente e então integrados pelo cérebro em uma impressão global da qualidade do produto. Informações a respeito da qualidade sensorial de um produto podem ser obtidas a partir de seu perfil sensorial, que por sua vez, pode ser traçado com o uso da Análise Descritiva Quantitativa (PORTMANN e KILCAST, 1998).

Análise Descritiva Quantitativa (ADQ) foi desenvolvida por Stone et al. (1974) com o objetivo de caracterizar os atributos sensoriais percebidos em um produto, em termos quantitativos e qualitativos (STONE, BLEIBAUM e THOMAS, 2012). O componente quantitativo mede o grau ou intensidade de cada uma das características presentes no produto, enquanto que o qualitativo abrange os termos descritivos, denominados de atributos, que definem o perfil sensorial das amostras (MEILGAARD, CIVILLE e CARR, 2007).

A ADQ é uma metodologia que proporciona a obtenção de uma completa descrição de todas as propriedades sensoriais de um produto, representando um dos métodos mais completos e sofisticados para a caracterização sensorial de atributos importantes (STONE, BLEIBAUM e THOMAS, 2012; LAWLESS e HEYMANN, 1999).

As principais etapas relacionadas à ADQ são: pré-seleção de provadores, desenvolvimento da terminologia descritiva, treinamento e seleção de provadores, avaliação sensorial e análise dos resultados. Para o desenvolvimento da terminologia descritiva utiliza-se o método tradicional ou o método de rede (ou Grid).

No método tradicional, o produto é oferecido a cada provador da equipe, que em seguida terá que desenvolver uma lista completa de descritores que descrevam características de aparência, aroma, sabor e textura do produto. Posteriormente sob a supervisão de um líder, a lista de cada provador é discutida com toda a equipe e os termos mais utilizados irão compor a ficha de análise descritiva. No método de rede (MOSKOWITZ, 1983), as amostras são apresentadas aos pares ao provador, que em seguida deverá descrever as similaridades e diferenças entre as amostras. Posteriormente sob a supervisão de um líder, os termos de cada provador são discutidos com a equipe e é feita uma lista consensual de termos. E os provadores deverão sugerir materiais de referência que ajudarão a equipe na percepção das características e ancorar os extremos das escalas de intensidade.

Os provadores que participam desta análise devem possuir capacidade descritiva, identificando os diferentes estímulos, capacidade discriminativa, percebendo diferenças mínimas de intensidade destes estímulos e capacidade quantitativa, sendo capazes de utilizar a escala em toda sua amplitude, com pequena dispersão entre as repetições e em consenso com a equipe de provadores.

Quando associada a estudos afetivos de consumidor, permite obter conclusões de grande importância, como, identificar quais as características sensoriais e em que intensidade está presente nos produtos mais ou menos aceitos pelos consumidores. Possibilita ainda verificar se produtos concorrentes diferem sensorialmente entre si e em quais atributos há diferença (MEILGAARD, CIVILLE e CARR, 2007).

Wheeler, Shackelford e Koohmaraie (1998) com o objetivo de comparar os efeitos de dois métodos de cocção (forno e "*grill*") na palatabilidade de bifes de contráfilé, concluíram que os provadores treinados detectaram diferenças ($p<0.01$) de maciez e suculência entre os métodos.

Amostras de contrafilé foram submetidas a um método de cocção (forno) com seis temperaturas internas finais (55, 60, 63, 71, 77 e 82°C). Os resultados de força de cisalhamento indicaram que a maciez das amostras diminuiu ($p<0.05$) com o aumento da temperatura. Com relação aos provadores, para a suculência e maciez, entre 55 e 60°C não foram encontradas diferenças entre si ($p>0.05$), assim como também nas temperaturas entre 71 e 77°C. Diferenças ($p<0.05$) foram encontradas na temperatura de 82°C em relação às outras temperaturas (LORENZEN et al., 2005).

De acordo com Schmidt et al. (2010), provadores avaliaram dois tipos de amostras (classificadas de acordo com o grau de mármore – "select" e "choice") de contrafilé assadas com cinco temperaturas internas finais (60, 66, 71, 74 e 77°C). O aumento de 60 a 71°C proporcionou uma diminuição nas médias de maciez e suculência ($p<0.05$). Entre as temperaturas de 71 e 77°C, os provadores não encontraram diferenças para os mesmos atributos nos dois tipos de amostras analisadas.

3.2.2. Análise Tempo-Intensidade

A metodologia Tempo-Intensidade é um tipo de análise descritiva que avalia as mudanças na percepção de um determinado atributo ao longo do tempo (MCGOWAN e LEE, 2006). Este teste sensorial vem ganhando especial atenção ao longo do tempo, principalmente, porque, com o rápido desenvolvimento da informática nos últimos anos, a principal dificuldade do teste, que era a coleta de dados, tem sido muito facilitada (BOLINI-CARDELLO et al., 2003). Este teste foi definido por Amerine, Pangborn e Roessler (1965) como medida da velocidade, duração e intensidade por um estímulo único, ou seja, mede a intensidade do estímulo percebido de acordo com o tempo percorrido.

Silva (1999) pode verificar a evolução das metodologias para avaliação dos atributos sensoriais temporais dos alimentos. Sendo assim, pode classificá-las em três gerações: a primeira geração que foi desenvolvida por Larson-Powers e Pangborn em 1978, considerada como mecânica consistia na técnica de que o provador marcava com um lápis a intensidade da sensação percebida sobre uma escala em um papel, que se movia sob velocidade constante; a segunda geração baseava-se na metodologia de avaliações sensoriais temporais em potenciômetros, a partir da proposta de Birch e Munton, em 1981; e a terceira e atual geração, baseia-se na utilização de microcomputadores para o desenvolvimento de metodologias de avaliação tempo-intensidade.

O aroma, gosto, texturas, sensações térmicas e picantes, presentes em alimentos e bebidas variam à medida que o produto é avaliado. Por isso, desenvolveu-se um método sensorial indicado para estes casos, o tempo-intensidade, pois provê informações sensoriais temporais sobre o estímulo percebido durante todo o tempo de contato com a mucosa oral, mudando de momento para momento durante os processos de mastigação, respiração, salivação, movimento da língua e ingestão (LEE e PANGBORN, 1986; LAWLESS e HEYMANN, 1999). Em certos casos, o período de persistência de uma determinada sensação pode ser importante (AMERINE, PANGBORN e ROESSLER, 1965).

A avaliação sensorial por meio da metodologia tempo-intensidade é um prolongamento da análise sensorial clássica através de escalas, provida de informações temporais sobre a sensação percebida (CLIFF e HEYMANN, 1993). O tempo requerido para que os sítios receptores dos botões gustativos respondam a um estímulo constante depende do tipo e da concentração dos estímulos presentes e a interação entre os alimentos e a saliva (YAMAMOTO et al., 1982). Em outras palavras, a percepção da intensidade máxima para um composto específico ou ingrediente é uma função do tempo e da concentração do estímulo.

Diferentes estímulos sensoriais possuem uma característica em comum no decorrer do tempo, que é o aumento da percepção seguido de uma intensidade máxima, que caminha para a extinção (KELLING e HALPERN, 1983). Em alguns casos, o período de persistência de uma determinada sensação pode ser importante. De maneira geral, os parâmetros frequentemente analisados das curvas obtidas por esta metodologia são: a área total sob a curva, o tempo total de duração, a intensidade máxima do estímulo e o tempo em que a intensidade máxima foi atingida (UJIKAWA e BOLINI, 2004; CAVALLINI e BOLINI, 2005; MARCELLINI, 2005).

Pesquisadores têm desenvolvido procedimentos de análise tempo-intensidade automatizada e computadorizada, empregando diferentes instrumentos e representações visuais de escalas (DUIZER, GULLET & FINDLAY, 1993). No Brasil foi desenvolvido o programa SCDTI (Sistema de coleta de dados Tempo-Intensidade) no Laboratório de Análise sensorial da Faculdade de Engenharia de Alimentos – UNICAMP (BOLINI-CARDELLO et al., 2003).

Em relação aos produtos cárneos, dentre os estímulos sensoriais mais importantes são os de textura, pois este é um fator importante na aceitação do consumidor. Diante disso, os atributos mais importantes para a textura da carne são a maciez e suculência (ZIMOCH e GULLET, 1996; BUTLER, POSH, MACKIE, e JONES, 1996; OBUZ et al., 2004; WALSH et al., 2010).

Esta técnica têm sido usada para analisar muitas matrizes de alimentos como chocolates (PALAZZO et al., 2011), sorvetes (CADENA e BOLINI, 2011), café (MORAES e BOLINI, 2010), gelatina sabor framboesa (PALAZZO e BOLINI, 2009), demostrando assim a importância deste tipo de técnica em avaliação sensorial de alimentos. Quanto aos produtos cárneos, os primeiros estudos que aplicaram a análise tempo-intensidade, avaliaram as mudanças da maciez da carne durante a mastigação (BUTLER, POSH, MACKIE, e JONES, 1996; ZIMOCH e GULLET, 1996). Recentemente Emrick et al (2005) e Reinbach, Toft e Moller (2009) analisaram a percepção temporal de sabor em carne de frango e carne de porco, respectivamente. A percepção de sal também foi estudada em presunto curado através da análise tempo-intensidade (BERTRAM et al., 2005) e os efeitos da gordura e do teor de NaCL na percepção temporal de sabor e textura de mortadela cozida (VENTANAS et al., 2010) também foram realizados.

Brown, Gérault e Walkeling (1996) utilizaram o método tempo-intensidade para investigar os critérios usados por julgadores não treinados em métodos sensoriais clássicos na avaliação da maciez e suculência de filés de carne bovina e suína. As formas das curvas tempo intensidade para a maciez e suculência diferiram entre os julgadores, mas evidenciaram similaridades para os dois atributos individualmente. Alguns julgadores afirmaram que a suculência aumentou durante a mastigação. Os resultados indicaram que os julgadores diferiram em seus conceitos sensoriais de maciez e suculência. Os autores sustentaram o uso do método tempo-intensidade para a interpretação de diferenças individuais na percepção sensorial.

Zimoch e Gullet (1996) avaliaram divergências temporais na percepção dos atributos suculência e maciez em contrafilés bovinos e diferenças entre as amostras de contrafilé. A análise de componentes principais dos dados tempo-intensidade indicou boa homogeneidade da equipe sensorial, tanto para a maciez quanto para a suculência. Os autores encontraram correlações significativas entre a maciez e a suculência para os parâmetros tempo para a intensidade máxima e duração total do estímulo. Concluiu-se que, com base nos resultados a suculência, ao contrário da maciez, persistiu toda a mastigação até a deglutição da amostra e então finalizou-se subitamente. A secreção da saliva durante a mastigação influenciou a percepção da suculência, contribuindo assim para a sustentabilidade da fase pós-máx.

Butler et al. (1996) avaliaram carne suína que foi submetida a um forno convencional pré-aquecido (160, 170 e 180°C) com uma temperatura interna final de 80°C. Os provadores que realizaram o teste tempo-intensidade para a percepção de maciez, não encontraram diferenças entre as amostras, quando comparadas as temperaturas do forno.

3.2.3. Análise de Aceitação

Os testes afetivos, também chamados de testes de consumidor, são importantes ferramentas, pois permitem a determinação da opinião direta (preferência e/ou aceitação) do consumidor potencial de um produto sobre suas características específicas (MINIM et al., 2006).

A análise de aceitação mede o quanto uma pessoa gosta ou não de um determinado produto ou sua preferência. Preferência é a expressão do apelo de um produto em relação ao outro. A preferência pode ser medida diretamente, por meio da comparação entre dois ou mais produtos entre si. A medida indireta deste teste pode ser alcançada verificando-se qual produto apresentou maiores notas sensoriais (preferido) em relação a outro, em um teste com várias amostras, ou qual produto obteve escolha por um maior número de pessoas em relação ao outro, significativamente (STONE, BLEIBAUM e THOMAS, 2012).

Os testes de aceitação podem ser classificados de acordo com o local de aplicação, em testes de laboratório, de localização central e de uso doméstico, sendo que todos apresentam vantagens e desvantagens que devem ser avaliadas antes da utilização e aplicação (STONE, BLEIBAUM e THOMAS, 2012).

Estes testes são realizados com indivíduos sem nenhum treinamento prévio nas técnicas de avaliação sensorial. Por este motivo, são esperadas respostas que resultem de reações espontâneas dos provadores ao provarem ou avaliarem as amostras. Nesses testes, pode-se também determinar a aceitabilidade, intenção de compra, além da preferência pelos produtos (ALMEIDA et al., 1999).

A escala hedônica é provavelmente o teste afetivo mais utilizado, pois possibilita calcular a média e a magnitude da diferença entre a aceitação dos produtos, construir a distribuição de frequência dos valores hedônicos e verificar possíveis segmentações de opiniões de consumidores (STONE, BLEIBAUM e THOMAS, 2012). As escalas do ideal ou "just about right scale" são escalas no qual o indivíduo expressa o quão ideal o produto está em relação à intensidade de um atributo específico. Os dados podem ser analisados por histogramas de frequência, ou comparando a distribuição das respostas das amostras com as de uma amostra padrão ou de uma marca de sucesso pelo teste qui-quadrado (MEILGAARD, CIVILLE e CARR, 2007).

Quando testes afetivos são analisados por técnicas estatísticas univariadas, parte-se do pressuposto que o critério de aceitabilidade utilizado por cada consumidor é homogêneo. Em outras palavras, considerar as avaliações de todos os consumidores em conjunto implica assumir que todos apresentam o mesmo comportamento, desconsiderando suas individualidades. Como consequência, pode ocorrer que os dados não sejam bem visualizados a ponto de se perder informações interessantes sobre diferentes segmentos de mercado, bem como obter resultados que não refletem a média real (BOLINI-CARDELLO e FARIA, 1999; SILVA et al., 1998). Por esta razão, uma forma interessante de expressar os resultados obtidos por testes de consumidor é o Mapa de Preferência, que considera a variabilidade individual dos dados.

O Mapa de Preferência é uma técnica estatística de análise multivariada de preferência, originadas da psicrometria e baseadas em estudos desenvolvidos por pesquisadores americanos. Os dados podem ser testados de duas maneiras: por análise interna ou externa. O Mapa de Preferência Interno é uma ferramenta estatística que permite a avaliação individual da preferência dos consumidores em relação ao conjunto. Com ele, as respostas individuais de cada provador geram um espaço multidimensional representado por dimensões de preferência que explicam a variação total entre as amostras (MORAES, 2004). Aliado à análise de variância e teste de médias, o Mapa de Preferência Interno pode complementar a análise de aceitação de um produto, explicando as preferências dos consumidores e tornando as informações obtidas mais valiosas (BOLINI-CARDELLO e FARIA, 2000).

Segundo Schmidt et al. (2010), consumidores (n=156) que avaliaram amostras “select” (classificação de carcaça de acordo com o grau de mármore) de contrafilé bovino assadas em cinco temperaturas (60, 66, 71, 74 e 77°C), não encontraram diferenças ($p>0,05$) entre os tratamentos para os atributos de aparência, aroma, sabor e aceitação global. Entretanto, preferiram ($p<0,05$) a textura das amostras assadas a 66°C em relação às outras.

De acordo ainda com Schmidt et al. (2010) consumidores (n=155) que avaliaram as amostras (“choice”), não encontraram diferenças ($p>0,05$) entre os tratamentos para o aroma e sabor. Com relação à aparência, preferiram ($p<0,05$) bifes na temperatura de 71°C do que nas temperaturas de 60 e 77°C. Para a textura, os consumidores preferiram amostras assadas em 60 e 66°C em relação aos outros tratamentos e a temperatura de 77°C foi a menos preferida ($p<0,05$).

De acordo com Lorenzen et al. (2005), consumidores (n=96) não encontraram diferenças ($p>0,05$) no sabor e aceitação global de amostras de contrafilé assadas nas temperaturas internas (55, 60, 63, 71, 77 e 82°C). Entretanto, as amostras assadas de 55 a 60°C tiveram notas mais altas ($p<0,05$) para maciez e suculência, e não houve diferença ($p>0,05$) nas amostras de 71 e 77°C, mas estas, porém diferiram ($p<0,05$) de temperaturas mais baixas e de 82°C. De acordo com Savell et al.(1999) amostras de contrafilé assadas, também não diferiram no atributo aceitação global para as diferentes temperaturas internas finais estudadas.

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5. ARTIGO 1

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SENSORY DESCRIPTIVE PROFILING AND CONSUMERS PREFERENCES OF BEEF STRIP LOIN STEAKS

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5.1. Abstract

The primary objectives of this study were to determine the descriptive sensory profile of beef strip loin steaks cooked two ways (oven and griddles) to three end-point temperatures (65, 71 and 77°C) and to investigate the acceptability of these steaks to consumers; secondary objectives involved determining the drivers of consumer preference and understanding the relationship between descriptive attributes and hedonic judgments using partial least squares (PLS) regression analysis. The Warner–Bratzler shear force of the meat and cooking losses were analyzed. Descriptive sensory profiling was performed by 13 trained evaluators using quantitative descriptive analysis (QDA). The acceptability of the steaks was tested with 118 beef consumers. QDA revealed that all attributes except fat aroma and liver flavor differed significantly by sample. PLS regression analysis was not able to identify the descriptors that were positively or negatively associated with the acceptability of the beef strip loin samples. Consumers preferred the appearance, aroma and flavor of beef strip loin samples cooked at the highest temperatures and the tenderness and juiciness of samples cooked at the lowest temperatures.

Keywords: Beef strip loin, cooking method, end-point temperature, sensory analysis, beef sensory descriptors, PLS

5.2. Introduction

Appearance, juiciness, flavor and texture are some of the most important sensory attributes of meat (Wheeler, Shackelford & Koohmaraie, 1999). Studies have evaluated different cooking methods and end-point temperatures to compare the efficiencies and effects of the cooking methods on the Warner-Bratzler shear force of the meat and on cooking losses; however, few studies have performed sensory analysis to compare these cooking methods (Obuz, Dikeman, Grobbel, Stephens & Loughin, 2004, Yancey, Wharton & Apple, 2011). Some studies have performed descriptive sensory analysis of the flavor and texture of beef; however, no studies have used quantitative descriptive analysis (QDA) to evaluate meat cooked with different methods to different end-point temperatures (Lorenzen, Davuluri, Adhikari, & Grun, 2005, Schimdt et al., 2010). QDA provides a complete description of the sensory properties of a product and is one of the most complete and sophisticated methods used for the sensory characterization of important attributes (Stone et al, 2012).

According to Lorenzen et al. (1999), Neely et al. (1999) and Savell et al. (1999), the cooking method and meat preparation technique can affect the sensory perception of beef consumers. According to Schmidt et al. (2010) and Sasaki et al. (2010), insufficient information on meat preparation methods (especially regarding the most appropriate method and end-point temperature for beef cuts) is available to consumers (Garcia-Segovia, Bello & Monzó, 2007). Therefore, it is important to acquire data on the preparation and cooking of meat to generate more accurate data for consumers. Consumers are interested in convenient cooking methods that offer an acceptable level of palatability for meat (Jeremiah, Gibson, Aalhus & Dugan, 2003). The electric griddles (different from the oven) is used in most beef-related studies and is a popular method commonly used in hotels and industrial restaurants. One study evaluated strip loin steaks (m. *longissimus thoracis)* cooked with five different methods (including the griddles) to three end-point temperatures; however, this study did not involve sensory analysis (Yancey, Wharton & Apple, 2011).

The aims of the present study were as follows: (1) to determine the descriptive sensory profile of beef strip loin steaks cooked with two cooking methods (oven and griddles) to three end-point temperatures (65, 71 and 77°C) and to gauge consumer acceptance of these meats; (2) to determine drivers of consumer preference and understand the relationship between descriptive attributes and hedonic judgments using partial least squares (PLS) regression analysis.

5.3. Materials and Methods

5.3.1. Meat samples

Strip loin samples (n=100) (m. *longissimus lumborum)* with the same degree of fat thickness from the 12^{th} rib to the second lumbar vertebra of the left side of the carcass of similarly aged Angus animals were collected. The subcutaneous fat was trimmed from these samples and the samples were vacuum packed and aged for 14 days (2ºC). At the end of the aging period, the sample was frozen (-20ºC). After freezing, each piece was cut into six 2.54-cm thick steaks (perpendicular to the steak surface). The steaks remained vacuum packed and frozen until instrumental and a sensory analysis. The following analyses were performed: cooking loss (CL); Warner–Bratzler shear force (WBSF); quantitative descriptive analysis by trained assessors (QDA) and a consumer acceptance test.

5.3.2. Cooking

The steaks were thawed at 4°C for 24 hours. The procedures used to cook the steaks intended for sensory evaluation were based on a modified experimental protocol described by the American Meat Science Association (AMSA, 1995). Six treatments were applied to the steaks: two cooking methods (oven and griddles) and three end-point temperatures (65, 71 and 77°C). The internal temperatures were monitored by copper/constantan thermocouples (Type T; Pyrotec Automação Ltda., Sousas, state of São Paulo-SP, Brazil) inserted in the geometric center of each steak and connected to a digital temperature meter (Pyrotec Automação Ltda., Sousas, SP, Brazil).

The electric counter-top griddles (model CE 65; Power Fire Ldta., Rio de Janeiro, State of Rio de Janeiro-RJ, Brazil) was preheated for 30 minutes and the temperature was maintained between 150 and 170°C. To avoid prolonged contact of the steak surface with the griddles, the steaks were turned every 30 seconds for the first three minutes then every minute until the specified end-point temperature (65, 71 and 77°C) was reached.

The conventional electric oven (model 45X60 – 3,000 W; Fritomaq Ltda., São Paulo, SP, Brazil) was preheated for 30 minutes on the "high" setting and the temperature was maintained between 130 and 150°C. The steaks were placed on a set consisting of a tray and aluminum grill. After the internal temperature reached its halfway point (32.5, 35.5 and 38.5°C), the steaks were turned so that they were cooked to a similar degree on both sides. The steaks remained in that position until the end-point temperature (65, 71 and 77°C) was reached; at this point, the steaks were removed from the oven.

5.3.3. Warner-Bratzler shear force analysis

After cooking, the steaks (n = 36 / 6 per treatment) were stored in plastic bags, labeled and refrigerated (4ºC / overnight) (AMSA, 1995). Six cylinders (1.27 cm) were removed from each steak using a coring cutter attached to a power drill (Bosch brand) in the lengthwise direction of the muscle fibers. Each cylinder was cut once using a TA-XT2® texture analyzer (Texture Technologies Corp./ Stable Micro Systems, UK) with a 1-mm-thick Warner-Bratzler blade.

5.3.4. Cooking loss

The cooking loss was measured by dividing the difference in the weights of the raw and cooked samples by the raw sample weight. All of the steaks intended for sensory analysis were weighed before and after cooking. The steaks were weighed immediately after they were removed from the oven and griddles.

5.3.5. Sensory Analysis

The sensory analysis was performed in individual air-conditioned booths (22°C) under white light. The assessors were instructed to rinse their mouths with distilled water between samples to avoid carry-over effect. The sessions were held at the Laboratory of Sensory Science and Consumer Studies of the School of Food Engineering / Department of Food and Nutrition of Campinas State University. The steaks were distributed according to a complete block design, alternating the position of steaks across treatments to minimize the effect of steak position (Macfie, Bratchell, Greenhoff & Vallis, 1989). After being roasted and grilled, the steaks were cut into 1.5 x 1.5 cm cubes and placed in labeled glass jars inside a yoghurt maker heated to approximately 40ºC. Appearance was assessed by the assessors using entire steaks. To describe the aroma, flavor and texture of the meats, the assessors received two cubes of meat served in a ramekin labeled with three digit numbers and a porcelain plate heated to 50°C in an electric heater. Approval for the study was obtained from the Ethics Committee of the University of Campinas, and written consent was provided by all volunteers. The descriptive sensory profile of the six beef strip loin steak samples was established using QDA (Stone et al, 2012).

Pre-selection of Assessors

Subjects were pre-selected by paired-testes applied to Wald's sequential analysis (Meilgaard, Civille & Carr, 2007). The samples to paired-tests were prepared and the difference in texture was tested for significance at the 0.1% level. Each evaluator performed the tests to sequential analysis with nine replicates. Thirty individuals who performed the paired-tests, fifteen judges were pre-selected.

Development of Descriptive Terminology

The network method (Moskowitz, 1983) was used at this stage to determine the descriptors for beef strip loin steaks in the six treatments. The samples were presented in pairs and each taster described the similarities and differences in appearance, aroma, flavor and texture of each pair. After a discussion among the team members during which irrelevant terms were eliminated, a total of 23 descriptors were developed along with their references (Table 1).

Training and Selection of Assessors

Nine two-hour-long training sessions were conducted. Analyses were performed over a six-day period, and each sample (and each repetition) was evaluated for 15 minutes.

To the selection of assessors, the six beef strip loin steak samples were evaluated in six repetitions in a monadic form following a balanced complete block design (Macfie, Bratchell, Greenhoff & Vallis, 1989). Analysis of Variance (ANOVA) Two-way, with two source variation (sample and repetition) to each descriptor term and each assessor was applied and the assessors were chosen to participate according to their discriminating capability ($p<0.50$) and repeatability ($p>0.05$) using data collected during the training sessions; individual consensuses were also considered (Damásio & Costell, 1991). Thirteen assessors were selected (11 women and 2 men, with ages ranging from 25 to 40 years).

Quantitative Descriptive Analysis

The thirteen selected assessors assessed six samples per session in a total of six sessions. Each evaluator received an assessment form and were invited to rate the intensity of each attribute on a linear scale with nine centimeters (unstructured) anchored on the left end by “weak”, “little” or “none” and on the right end by “strong” and “much” (Stone et al, 2012; Meilgaard, Civille & Carr, 2007).

Acceptance test

One hundred and eighteen beef consumers (47 male and 71 female aged between 18 and 30 years) were recruited to participate in the acceptance test. Individuals had to consume beef at least once per week and be older than 18 years. Each meat sample was assessed following a balanced complete block design (Macfie, Bratchell, Greenhoff & Vallis, 1989). The assessors were asked to assess the acceptability of six beef strip loin steak samples in terms of appearance, aroma, flavor, tenderness, juiciness and overall impression on an unstructured nine centimeters scale anchored by the terms "disliked very much" and "liked very much" (Stone et al, 2012; Meilgaard, Civille & Carr, 2007). Each assessor assessed the six beef strip loin steak samples in a single session.

The acceptability of appearance was rated based on the color and moistness of each sample; the aroma referred to the aroma of the meat, the acceptability of flavor was related to the flavor of the meat (taste) and the overall impression was related to the general acceptability of each sample. Each consumer had previously received information defining the attributes tenderness and juiciness. To prevent bias, no information on the cooking method or temperature of the sample was given to the consumers.

5.3.6. Statistical Analysis

The data on Warner-Bratzler shear force and cooking loss were analyzed following a 2x3 factorial experimental design (oven and griddles and three end-point temperatures of 65, 71 and 77°C) using the GLM procedure and Tukey's test in the Statistica 7.0 software (Statsoft, 2005).

The training of the assessors was validated for each descriptive term using ANOVA: in particular, the ability to discriminate ($p<0.50$), the repeatability of the assessor ($p>0.05$) and the inter-taster agreement (Damásio & Costell, 1991) was evaluated. Data related to physical and the statistical analysis applied to acceptance data shown in table 4 and QDA were analyzed by ANOVA, Two-way with two variations sources (assessor and sample). For both analyses, means were compared by Tukey's test when a significant difference ($p<0.05$) among samples was detected for any variable. The results were analyzed using the SAS software (2008). The correlation between QDA and acceptance test data was investigated by Partial least squares (PLS) regression (Tenenhaus, Pagès, Ambroisine & Guinot, 2005; Morais et al., 2014). The overall impression was the dependent variable (Y-matrix) and descriptive terms from the QDA were the independent variables (X-matrix). The External Preference Map (PREFMAP) was also drafted to analyze the descriptive and affective data generated in the present study (Cadena et al., 2012). These analyses were performed with XLStat software (2007).

5.4. Results and Discussion

5.4.1. Warner-Bratzler shear Force and Cooking Loss

The results associated with Warner-Bratzler shear force are shown in Table 2. The interaction between cooking method and end-point temperature did not significantly impact (P=0.54) shear force, which agreed with Yancey, Wharton & Apple (2011). As expected, the steaks prepared at 65°C had lower (P<0.05) shear force values, while those prepared at 77°C had greater values (P<0.05). Similar results were reported by Wheeler, Shackelford and Koohmaraie (1999), Lorenzen et al. (2003) and Schmidt et al. (2010); these authors used a single cooking method and found that the shear force increased (i.e., the tenderness decreased) (P<0.05) with increasing end-point temperature. Obuz, Dikeman, Grobbel, Stephens & Loughin (2004) also found that shear force increased with increasing end-point temperatures above 55°C in select and choice steaks (*Longissimus muscle*) cooked in a water bath and on a belt-grill. There were no significant differences (P>0.05) in Warner-Bratzler shear force among cooking methods. It happens probably due to tender steaks were used in the project. These results are according Kerth, Blair-Kerth & Jones (2003) and Lawrence, King, Yancey & Dikeman (2001), that also reported no differences in the WBSF of steaks cooked by conduction or convection, different from Yancey, Wharton & Apple (2011), that found the clam-shell grill and counter-top griddles methods, which transfer heat to the meat using conduction heating, resulted in greater shear forces (P<0.05) than the forced-air convection oven and impingement methods, which use convection heating. McKenna, King & Savell (2003) showed that steaks prepared with methods requiring long cooking times had lower shear force values. However, the results of the second experiment from the same authors are in agreement with those of the present study: indeed, the slower cooking method (electric broiling) and the more rapid method (clam-shell grilling) had equal impacts on the Warner-Bratzler shear force of the studied samples.

The interaction between cooking method and end-point temperature had a significant (P=0.002) impact on cooking loss (Figure 1), disagreeing from Yancey, Wharton & Apple (2011) found that the interaction between cooking method and end-point temperature did not significantly (P>0.05) impact cooking loss. As expected, the increasing end-point temperature, constantly increase levels of cooking loss in both cooking methods, from 65ºC to 77ºC. At 65ºC and 71ºC the cooking loss were similar between oven and griddle, while at 77ºC the oven had the great loss, probably due to the long cooking. Schmidt et al. (2010) and Yancey, Wharton & Apple (2011) reported that steaks prepared at 65°C had lower levels of cooking loss (P<0.05). Obuz, Dikeman, Grobbel, Stephens & Loughin (2004) reported that cooking losses increased (P<0.05) in *Longissimus muscle* steaks cooked in a water bath or on a belt-grill when the end-point temperature increased from 40 to 80°C. Regarding the effect of cooking method, Yancey, Wharton & Apple (2011) did not find significantly different for cooking losses (P>0.05) in steaks (*Longissimus thoracis*) cooked using forced-air (convection oven), gas-fired methods (open-hearth charbroiler), counter-top griddles, forced-air (impingement oven) or electric clam-shell grills.

5.4.2. Quantitative Descriptive Analysis

The mean values for sensory attributes (appearance, aroma, flavor and texture) of beef strip loin steak samples from the six treatments (m. *longissimus lumborum)* are shown in Table 3. For each cooking method, the descriptor "degree of doneness" (ranging from "rare" to "well-done" – AMSA, 1995) of the steaks increased (P<0.05) with increasing internal temperature. The steaks cooked in the oven and on the griddles at 77°C had significantly greater (P<0.05) degrees of doneness than the other samples; the steaks cooked in the oven and on the griddles at 65°C had significantly lower degrees of doneness (P<0.05). The steaks cooked in the oven and on the griddles at 65°C had the greatest red internal color and apparent juiciness (P<0.05); the steaks cooked in the oven and on the griddles at 77°C had the lowest values of these attributes (P<0.05). The brown internal color of the steaks was greatest (P<0.05) and lowest (P<0.05) in the steaks cooked at 77°C and 65°C, respectively.

The roasted beef aroma was highest (P<0.05) and lowest (P<0.05) in the steaks cooked at 77°C and 65°C, respectively. For the same aroma steaks prepared using the oven and griddles at 71°C were significantly different from each other (P<0.05).

The toasted beef aroma and toasted beef flavor of steaks prepared on the griddles at 77°C were significantly different (P<0.05) from those of the other samples. This result was expected because of the direct contact between the steaks and the griddles. For the same aroma and flavor of the steaks prepared in the oven at 65°C and 71°C were similar to each other (P>0.05) but significantly different from steaks roasted at 77°C and grilled at 65 and 71°C. Lorenzen, Davuluri, Adhikari, & Grun (2005) reported the steaks roasted in the open hearth broiler at 82°C were statistically different ($P<0.05$) for flavor compared with 55, 60, 63, 71 and 77°C, in the same cooking method.

There were no significant differences ($P>0.05$) in the roasted beef flavor of steaks cooked in the oven and griddles prepared at 71 and 77°C. Lorenzen, Davuluri, Adhikari, & Grun (2005), found that steaks roasted at 77°C were not significantly different (P>0,05) from grilled steaks at 71°C for the roasted beef flavor. In the same way, Schmidt et al. (2010) found no significant differences in the aroma or flavor of steaks prepared in an oven at end-point temperatures of 60, 63, 71, 74 and 77°C. Otremba et al. (2000) found no significant differences ($P>0.05$) in the roasted flavor of steaks (*Longissimus* and *Semitendinosus*) cut two ways (long axis parallel to the direction of the muscle fibers and major axis perpendicular to the meat surface) cooked in a broiling oven at 71°C. However, Wheeler, Shackelford and Koohmaraie (1998) found that steaks (*Longissimus thoracis*) cooked at 70°C with the belt grill had lower beef flavor intensity than steaks cooked with electric broiler, at the same temperature.

The steaks prepared in the oven at 65°C had significantly ($P<0.05$) higher blood aroma and flavor scores than the steaks from the other treatments. Lorenzen, Davuluri, Adhikari, & Grun (2005) and Schmidt et al. (2010) who found that steaks prepared at 55 and 60ºC had greater blood flavor. The metallic flavor of steaks from the oven at 65°C were significantly higher ($P<0.05$) but did not differ statistically from steaks grilled at 65°C. Schmidt et al. (2010) found no significant differences ($P>0.05$) in metallic flavor between choice steaks

(*Longissimus lumborum*) prepared with five end-point temperatures (and the same cooking method). The steaks grilled on the griddles at 77°C had significantly higher saltiness scores than the steaks in the other treatments.

The tenderness of steaks roasted in the oven at 65°C tended to be greater ($P<0.05$) than that of steaks grilled on the griddles at 65°C. The tenderness of steaks prepared in the oven and on the griddles at 77°C was significantly lower than that of the remaining samples ($P<0.05$). The steaks prepared in the oven at 65 and 71°C and those prepared on the griddles at 65°C had the highest levels of juiciness ($P<0.05$), while those prepared in the oven and griddles at 77°C had the lowest levels of juiciness ($P<0.05$). Thus, the initial tenderness and juiciness of the samples decreased with increasing internal temperatures, while chewiness increased with decreasing end-point temperatures ($p<0.05$). Similar results were obtained in other studies (Lorenzen, Davuluri, Adhikari, & Grun, 2005, Sasaki et al., 2010; Schmidt et al., 2010; Yancey, Wharton & Apple, 2011). The tenderness results are consistent with results from the analysis of Warner-Bratzler shear force, which increased with increasing end-point temperature (Table 2).

Principal components analysis (Figure 2) enabled the comparison of the sensory attributes of steaks cooked or grilled in the oven and on griddles. Principal components I and II explained 70.50% of the variation in the samples. Analyzing the vectors corresponding to the attributes showed that most of the attributes contributed considerably to sample discrimination, as some of the vectors were located far from the origin.

The PCA plot shows that samples of steaks cooked and grilled in the oven and on the griddles at 65°C were mainly characterized by a blood aroma and flavor, a metallic flavor, juiciness, initial tenderness, apparent juiciness and internal red color. These results are according Schmidt et al. (2010) who had tasters describe the flavor (metallic or bloody), initial and sustained juiciness and initial and overall tenderness of steaks prepared at 60 and 63ºC. The steak samples prepared in the oven at 71°C were described mainly by a roasted beef aroma and flavor and a uniformity of surface color. Steak samples prepared on the griddles at 77°C were mainly characterized by a toasted aroma and flavor. The steak prepared in the oven at 77°C were characterized by a surface brown color, a degree of doneness, an internal brown color, chewiness and roast beef aroma and flavor.

Indeed, color of cooked meat product, as steaks, are determined by the behavior of meat pigments which under the action of heat are submitted to denaturation and interaction with other meat proteins, as conjunctive tissue. Towards the texture, the cooking induces structural changes as that reduce the water retention capacity reflecting mainly in the juiciness perception. Finally, along the cooking process, there are changes at the flavor profile as well as the arising of new ones from nonvolatiles precursors, resulting from the desamination of aminoacids, with the consequent formation of aldehydes hydrocabons, nitrites and amino compounds (Terra, Campos, & Campagnol, 2011).

5.4.3. Acceptance test

The results of the acceptance test performed by consumers (n=118) are shown in Table 4. Our findings suggests the steaks grilled on the griddles at 71°C had a high acceptance terms of appearance; however, the acceptability of these steaks did not differ significantly ($P>0.05$) from that of steaks prepared on the griddles at 65 and 77°C or in the oven at 71 and 77°C. The steaks cooked in the electric oven at 65°C had the lower acceptance in terms of appearance. In addition, the steaks grilled on the griddles at 77ºC had the tendency to higher acceptance aroma, but the acceptability of the aroma was similar ($P>0.05$) to that of the steaks prepared on the griddles at 65 and 71ºC or in the oven at 77°C. The steaks prepared in the oven at 65 and 71°C had the least accepted aroma ($P<0.05$). Regards to flavor, the steaks grilled on the griddles at 65°C had the tendency to higher acceptable flavor; however, the acceptability of these steaks was not significantly ($P>0.05$) different from that of the steaks prepared on the griddles at 71 and 77°C or in the oven at 77°C.

Regards to tenderness and juiciness, the steaks roasted in the electric oven at 65°C had the tendency to greater acceptable tenderness, but the acceptability of these steaks was not significantly ($P>0.05$) different from that of the steaks prepared on the griddles at 65°C and in the oven at 71°C; however, the acceptability of the steaks roasted in the electric oven at 65°C was significantly ($P<0.05$) different from that of the steaks prepared in the oven at 77°C and on the griddles at 77°C and 71°C. The steaks grilled on the griddles at 65°C had the tendency to higher acceptable juiciness, and the acceptability of the juiciness of these steaks did not differ significantly (P>0.05) from that of the steaks prepared in the oven at 65 and 71°C. The steaks prepared in the oven and on the griddles at 77°C and on the griddles at 71°C were the least acceptable in terms of juiciness, and the acceptability of these steaks differed significantly (P<0.05) from that of the other samples.

According to Schmidt et al. (2010), consumers cannot distinguish the appearance (P>0.05) of beef samples (*Longissimus lumborum*) cooked in an electric oven at 60, 66, 71, 74 or 77°C. The choice steak samples prepared at 71°C tended to be preferred by the consumers (P>0.05); the sample cooked at 60°C was the least preferred steak. In addition, the same authors found that consumers were not able to differentiate (P>0.05) samples of select and choice steaks prepared to five end-point temperatures.

Consumers did not notice differences in the appearance, aroma and flavor of steaks cooked on the griddles at the three end-point cooking temperatures studied. A possible explanation for this result is the way the steaks are processed, where they are directly in contact with the hot metal, and independent of the time they remain cooking, the appearance, aroma and flavor are formed rapidly and have little change with time.

Lorenzen, Davuluri, Adhikari, & Grun (2005) evaluated steaks prepared in an open-hearth broiler and found no significant differences (P>0.05) in the flavor and overall acceptability of steaks cooked to end-point temperatures of 55, 60, 63, 71, 77 and 82°C. Gilpin, Batcher & Deary (1965) and Schmidt et al. (2002) showed that rib and loin steak samples grilled at high temperatures also received low scores for juiciness and tenderness. Lorenzen et al. (1999), Neely et al. (1999), Goodson et al. (2002) and Savell et al. (1999) showed that the cooking method can affect evaluations of steaks by beef consumers.

The acceptability of tenderness and juiciness dropped as the internal temperature of the steak increased, which it can related to physic-chemical changes occurred by the steaks along the cooking process; an increased internal temperature is related to high water loss in the steak structure and browning, with direct influence about the texture attributes (juiciness, tenderness), appearance (color) and flavor of the steak, which are two recognized factors linked to acceptance of the meat products. The intrinsic judgments of the consumers perform a balance about the effect of these parameters and their respective interactions on the overall acceptance and indicate which one has higher prevalence. It seems there is a need to cook steaks in an intermediate temperature, as excessive and lower values of this end point temperature has a deleterious effect of the acceptance, suggesting that consumers are not able to tolerate the low juiciness and tenderness of the steaks in reason of an improved color and flavor.

A similar trend was found for the texture of the steak in QDA (Table 3) and for Warner-Bratlzer shear force (Table 2). A relationship between greater cooking losses (Table 2) and reduced juiciness was also detected by both the acceptance test and QDA. These findings indicate that the consumers were able to detect differences in tenderness and juiciness and that they preferred more tender and juicy steaks. Similar findings were obtained by Neely et al. (1999), Lorenzen et al. (1999, 2005) and Schmidt et al. (2010).

5.4.4. Relationship between Descriptive Attributes and the Acceptance Test

Correlating the descriptive data with the hedonic data from the samples by partial least squares (PLS) regression identified the attributes (and their levels of influence) that contributed positively and negatively to the acceptability of beef strip loin steak samples (Figure 3).

The columns containing descriptive terms that were located on the positive portions of the Y axis (or Standardized Coefficients) are considered to be positively correlated with the acceptability of the samples, while the columns that were on the negative portion of the Y axis represent the attributes that were negatively correlated with the acceptability of the samples.

The size of the columns represents the influence (both positive and negative) of the attribute on sample acceptability. Thus, larger columns indicate a greater influence of the descriptive term on the acceptability of the beef strip loin sample. It should be noted that when the vertical line that represents the interval of 95% confidence crosses the X axis, the influence of the correspondent attribute don’t have influence to driver the preferences of consumers.

PLS regression could not identify which attributes positively and negatively affected the acceptability of the beef strip loin steak samples prepared with two cooking methods (oven and griddles) to three end-point cooking temperatures (65, 71 and 77°C) at the 95% confidence interval.

5.4.5. External Preference Map

The results for the external preference map are shown in Figure 4. The data obtained explained two principal components. The horizontal component was responsible for splitting the attributes into two groups. The group of attributes associated with samples of rare steaks with a red internal color, a high apparent juiciness and a high initial tenderness and juiciness (texture) is located on the left. The group of attributes associated with samples of well-done steaks with a brown internal color, a roasted meat aroma and flavor and high levels of chewiness is located on the right. The vertical component was responsible for characterizing the samples. There were consumers groups near to all samples, and in regions which indicate lack of preference for any of specific sample. These show that for all cooking methods and temperatures there were consumers that enjoy it, without having a marked tendency to a particular sample.

5.5. Conclusions

The samples of steaks cooked in both methods at 65°C were mainly characterized by blood aroma and flavor, metallic flavor, juiciness, tenderness, apparent juiciness and internal red color, while in the oven at 71°C were mainly characterized by cooked aroma and flavor and uniformity of surface color. Steak samples prepared on griddles at 77°C were mainly characterized by roasted aroma and flavor, and prepared in oven at 77°C were characterized by surface brow color, degree of doneness, internal brow color and chewiness.

According the results obtained, the consumers that participated of study preferred the appearance, aroma and flavor of beef strip loin steak samples prepared at higher temperatures; however, they preferred the tenderness and juiciness of steaks prepared at lower temperatures. It was evident that the lowest temperature for both cooking methods resulted in the lowest levels of acceptability. Steaks grilled on the counter-top griddles at 65°C yielded a sample with a significantly greater acceptability in terms of all of the sensory characteristics analyzed.

The results may contribute significantly to the meat processors and food services establishments which serve steaks among the culinary dishes. In a practical point of view, intermediate end point temperatures are preferred to be used along the steak processing to balance the effect about the juiciness, tenderness, color and flavor of the steaks.

Acknowledgements

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Table 1. Descriptors used for the sensory profiling of beef striploin.

Descriptor	Definition	Reference
Surface brown color	Surface brown color intensity	Weak: 10 YR 7/ 4/ volume 1 (MUNSELL, 1976) Strong: 7.5 YR 3/ 4/ volume 1 (MUNSELL, 1976)
Surface color homogeneity	Surface color homogeneous and uniform	Less: beef inside round (0.025m) grilled in griddles (30 minutes/turned in 2 and 2 minutes) Much: beef inside round (0.025m) roasted in electric oven (71°C)
Internal brown color	Internal brown color intensity	Weak: 10 YR 7/ 4/ volume 1 (MUNSELL, 1976) Strong: 7.5 YR 3/ 4/ volume 1 (MUNSELL, 1976)
Internal red color	Internal red color intensity	Weak: 7.5 R 5/8/volume 1 (MUNSELL, 1976) Strong: 7.5 R 3/12/ volume 1 (MUNSELL, 1976)
Internal color	Degree of doneness	Less cooked: Very rare (AMSA, 1995) Much cooked: Very well done (AMSA, 1995)
Apparent juiciness	Amount of liquid at beef surface	None: beef inside round (0.025m) roasted in electric oven (75°C) Very: beef tenderloin (0.025m) roasted in electric oven (60°C)
Connective tissue presence	Amount of collagen fibers at beef surface	None: beef tenderloin (0.025m) roasted in electric oven (71°C) Very: beef shank (0.025m) roasted in electric oven (71°C)
Roast beef aroma	Intensity of roast beef aroma	Weak: beef inside round (0.04x0.04x0.025m) soaked in water for 12 hours, roasted in electric oven (71°C) Strong: beef inside round (0.04x0.04x0.025m) roasted in electric oven (71°C)
Toasted beef aroma	Intensity of toasted beef aroma	None: beef inside round (0.04x0.04x0.025m) soaked in water for 12 hours, roasted in electric oven (71°C) Strong: beef inside round (0.04x0.04x0.01cm) grilled in griddles (20minutes/turned in 30 in 30 seconds)
Boiled beef aroma	Intensity of boiled beef aroma	None: beef inside round (0.04x0.04x0.025m) soaked in water for 12 hours, roasted in electric oven (71°C) Strong: beef shank (0.025m) boiled in pressure

		cooker for 30 minutes
Blood aroma	Intensity of blood aroma	None: beef inside round (0.04x0.04x0.025m) soaked in water for 12 hours, roasted in electric oven (71°C) Strong: beef tenderloin (0.025m) roasted in electric oven (60°C)
Fat aroma	Intensity of fat aroma	None: beef inside round (0.04x0.04x0.025m) soaked in water for 12 hours, roasted in electric oven (71°C) Strong: beef rump (0.025m) wrapped with aluminum foil roasted in electric oven (75°C)
Roast beef flavor	Intensity of roast beef flavor	Weak: beef inside round (0.04x0.04x0.025m) soaked in water for 12 hours, roasted in electric oven (71°C) Strong: beef inside round (0.04x0.04x0.025m) roasted in electric oven (75°C)
Toasted beef flavor	Intensity of toasted beef flavor	None: beef inside round (0.04x0.04x0.025m) soaked in water for 12 hours, roasted in electric oven (71°C) Strong: beef inside round (0.04x0.04x0.01m) grilled in griddles (20minutes/turned in 30 in 30 seconds)
Boiled beef flavor	Intensity of boiled flavor flavor	None: beef inside round (0.04x0.04x0.025m) soaked in water for 12 hours, roasted in electric oven (71°C) Strong: beef shank (0.025m) boiled in pressure cooker for 30 minutes
Blood flavor	Intensity of blood flavor	None: beef inside round (0.04x0.04x0.025m) soaked in water for 12 hours, roasted in electric oven (71°C) Strong: beef tenderloin (0.025m) roasted in electric oven (60°C)
Fat flavor	Intensity of fat flavor	None: beef inside round (0.04x0.04x0.025m) soaked in water for 12 hours, roasted in electric oven (71°C) Strong: beef rump (0.025m) wrapped with aluminum foil roasted in electric oven (75°C)
Salty taste	Intensity of saltiness	None: beef inside round (0.04x0.04x0.025m) soaked in water for 12 hours, roasted in electric oven (71°C) Strong: beef inside round (0.04x0.04x0.025m) soaked in salted water (1%) for 2 hours, roasted in electric

		oven (71°C)
Metallic flavor	Intensity of metal / iron flavor	None: beef inside round (0.04x0.04x0.025m) soaked in water for 12 hours, roasted in electric oven (71°C) Strong: beef inside round (0.04x0.04x0.025m) soaked in solution of ferrous sulfate (0.5%) for 2 hours, roasted in electric oven (71°C)
Liver flavor	Intensity of liver flavor	None: beef inside round (0.04x0.04x0.025m) soaked in water for 12 hours, roasted in electric oven (71°C) Strong: beef inside round punctured (0.04x0.04x0.025m) involved with beef liver for 12 hours, roasted in electric oven (71°C)
Initial tenderness	Minimum force necessary (first bite) to bite the meat sample with incisors teeth	Less: beef outside round (0.04x0.04x0.025m) roasted in electric oven (75°C) Very: beef tenderloin (0.025m) roasted in electric oven (65°C)
Juiciness	Amount of liquid released during chewing with the molar teeth	Less: beef outside round (0.04x0.04x0.025m) roasted in electric oven (75°C) Very: beef tenderloin (0.025m) roasted in electric oven (65°C)
Chewiness	Time and strength (energy) required to chew the sample with the molars until swallowing	Less: beef tenderloin (0.025m) roasted in electric oven (65°C) Very: beef outside round (0.04x0.04x0.025m) roasted in electric oven (75°C)

Table 2. Shear force (WBSF) means ± SD of beef striploin cooked at 65, 71 and 77°C using electric oven and electric griddles.

	WBSF (kg)
Cooking method	
Oven	3.5 ± 0.64[a]
Griddles	3.8 ± 0.69[a]
Temperature	
65 ºC	3.1 ± 0.43[b]
71 ºC	3.5 ± 0.35[b]
77 ºC	4.2 ± 0.70[a]
SE	0.1
Method*Temperature	P = 0.54

[a,b] Means with the same letter in a column, for the same trait, do not differ ($P < 0.05$).

Table 3. Mean scores of descriptive attributes of beef strip loin steaks.

	Cooking method	Oven			Griddles			Pooled Standard Deviation
	Temperature (°C)	65	71	77	65	71	77	
Appearance Descriptor	Surface brown color	3.7^{d}	4.9^{c}	7.0^{a}	3.1^{d}	4.6^{c}	6.2^{b}	1.7
	Surface color homogeneity	6.2^{a}	6.1^{a}	6.0^{a}	2.9^{b}	2.5^{bc}	2.0^{c}	2.2
	Internal brown color	1.9^{c}	3.9^{b}	5.4^{a}	1.7^{c}	3.6^{b}	5.3^{a}	1.8
	Internal red color	4.7^{a}	3.0^{b}	0.8^{c}	4.9^{a}	2.7^{b}	1.1^{c}	1.9
	Degree of doneness	2.3^{c}	4.5^{b}	6.6^{a}	2.1^{c}	4.4^{b}	6.3^{a}	2.0
	Apparent juiciness	5.9^{a}	4.6^{b}	2.0^{c}	5.6^{a}	4.3^{b}	2.1^{c}	2.0
	Connective tissue presence	0.8^{a}	0.8^{a}	0.8^{a}	0.8^{a}	0.8^{a}	0.8^{a}	0.6
Aroma Descriptor	Roast beef	3.1^{d}	4.5^{c}	6.1^{a}	3.2^{d}	4.9^{b}	6.3^{a}	1.5
	Toasted beef	0.6^{e}	0.8^{e}	1.3^{d}	2.6^{c}	4.1^{b}	5.7^{a}	2.1
	Cooked beef	2.6^{b}	3.2^{a}	2.2^{cd}	2.3^{bc}	1.8^{d}	1.4^{e}	1.1
	Blood	1.5^{a}	0.8^{c}	0.6^{d}	1.1^{b}	0.5^{d}	0.5^{d}	0.7
	Fat	0.8^{a}	0.8^{a}	0.7^{a}	0.8^{a}	0.7^{a}	0.7^{a}	0.5
Flavor Descriptor	Roast beef	2.8^{d}	4.3^{b}	6.1^{a}	3.2^{c}	4.7^{b}	6.1^{a}	1.5
	Toasted beef	0.6^{e}	0.7^{e}	1.1^{d}	2.6^{c}	4.0^{b}	5.6^{a}	2.1
	Cooked beef	2.6^{b}	3.2^{a}	2.0^{c}	2.2^{b}	1.8^{c}	1.3^{d}	1.1
	Blood	1.6^{a}	0.9^{c}	0.7^{d}	1.3^{b}	0.7^{d}	0.6^{d}	0.7
	Fat	0.7^{a}	0.7^{a}	0.5^{b}	0.7^{a}	0.7^{ab}	0.6^{ab}	0.4
	Salty Taste	0.7^{c}	0.7^{c}	0.9^{b}	0.7^{bc}	0.9^{bc}	1.1^{a}	0.5
	Metallic	1.1^{a}	0.7^{bc}	0.6^{c}	0.9^{ab}	0.7^{c}	0.6^{c}	0.6
	Liver	0.6^{a}	0.5^{a}	0.5^{a}	0.6^{a}	0.6^{a}	0.5^{a}	0.4
Texture Descriptor	Initial tenderness	7.3^{a}	6.9^{b}	5.6^{d}	7.2^{ab}	6.5^{c}	5.5^{d}	4.5
	Juiciness	7.0^{a}	6.6^{a}	5.4^{c}	6.9^{a}	6.1^{b}	5.2^{c}	1.2
	Chewiness	1.4^{c}	1.7^{bc}	2.6^{a}	1.5^{c}	2.0^{b}	2.8^{a}	1.1

[a,b] Means with the same letter in a row do not differ ($P < 0.05$).

Table 4. Sensory acceptance of beef strip loin steaks.

Cooking method	Oven			Griddles			Pooled Standard Deviation
Temperature (°C)	65	71	77	65	71	77	
Appearance	5.3^{b}	5.8^{ab}	6.0^{a}	5.9^{a}	6.2^{a}	6.0^{a}	2.0
Aroma	5.1^{b}	5.4^{b}	6.1^{a}	6.3^{a}	6.4^{a}	6.5^{a}	2.1
Flavor	5.2^{c}	5.7^{bc}	6.0^{ab}	6.3^{a}	6.3^{a}	6.1^{a}	2.1
Tenderness	6.8^{a}	6.3^{ab}	6.1^{b}	6.7^{a}	6.0^{b}	5.8^{b}	2.1
Juiciness	6.3^{ab}	6.2^{ab}	5.8^{b}	6.6^{a}	6.0^{b}	5.8^{b}	2.1
Overall impression	5.85^{c}	5.9^{bc}	6.1^{abc}	6.6^{a}	6.3^{ab}	6.1^{bc}	1.9

[a,b] Means with the same letter in a row do not differ ($P < 0.05$).

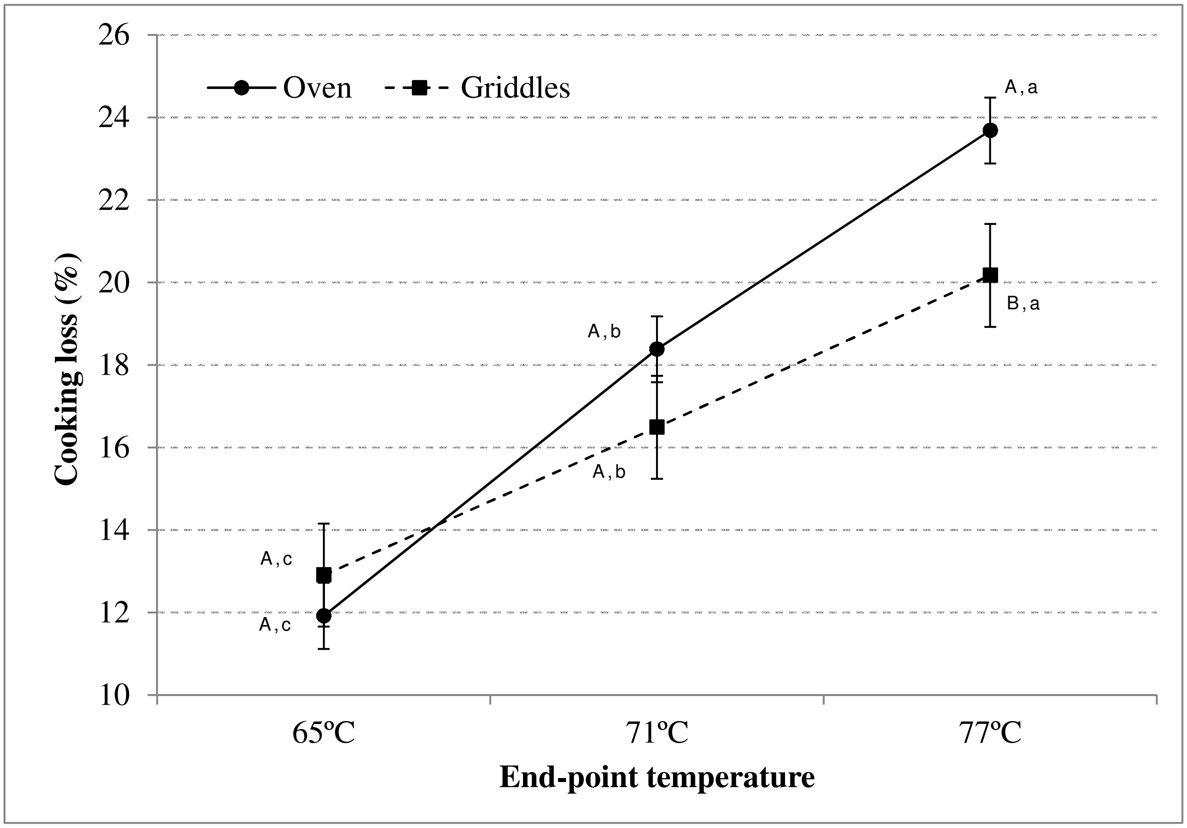

Figure 1. The relationship between cooking method and end-point temperature for cooking loss (P = 0.002). [A,B]Means with the same letter for the same end-point temperature do not differ (P > 0.05). [a,b,c]Means with the same letter for the same cooking method do not differ (P > 0.05)

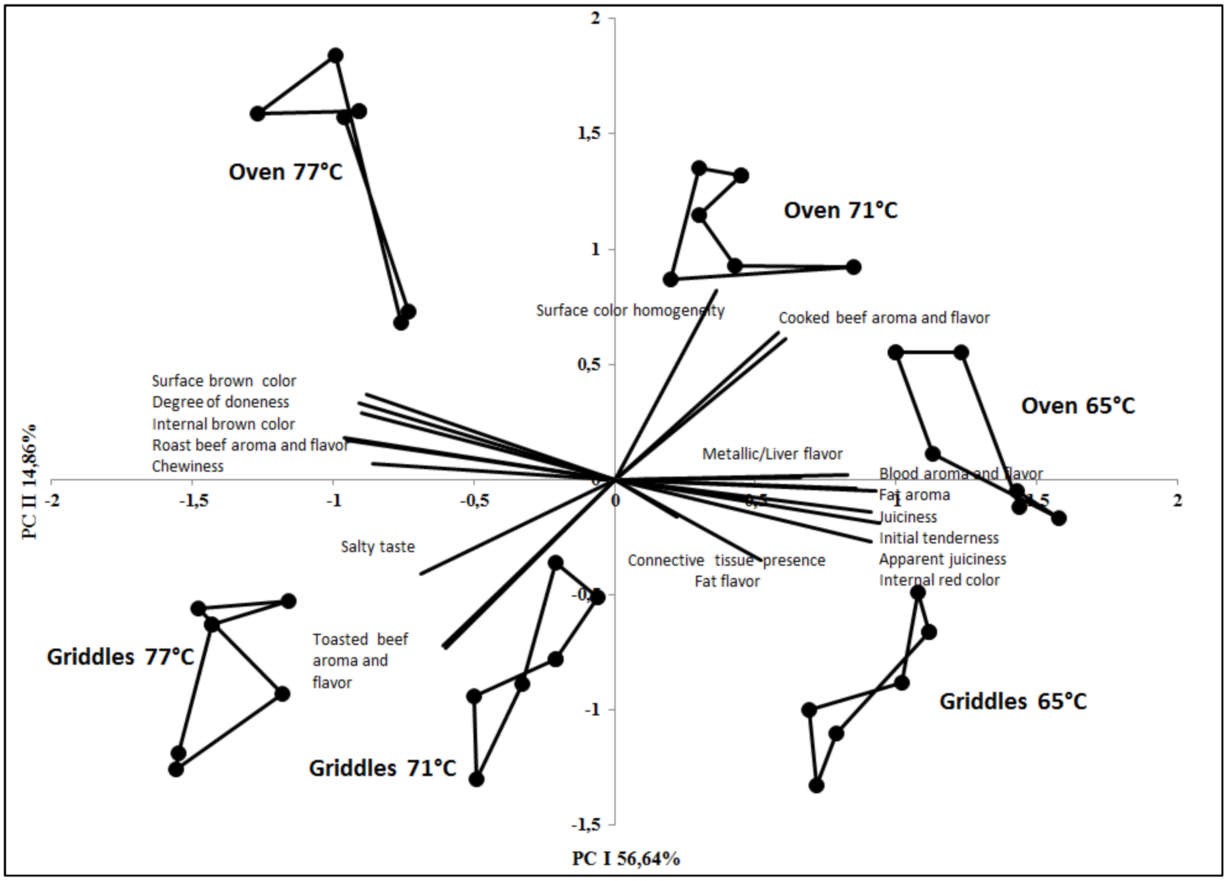

Figure 2. Principal components analysis of beef strip loin steaks

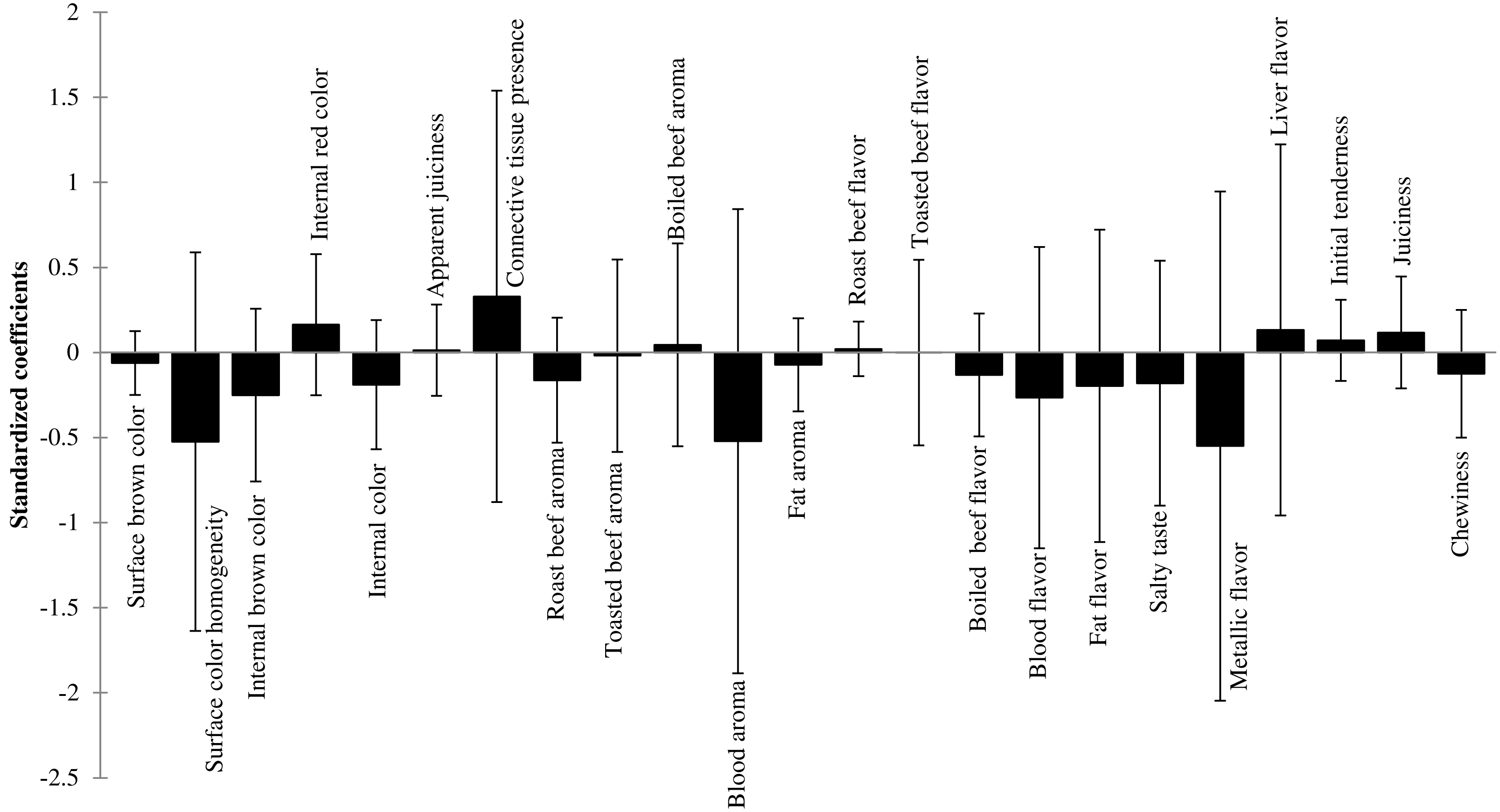

Figure 3. Partial least squares standardized coefficients of beef strip loin steaks (black = descriptor terms without significant contribution to consumer acceptance)

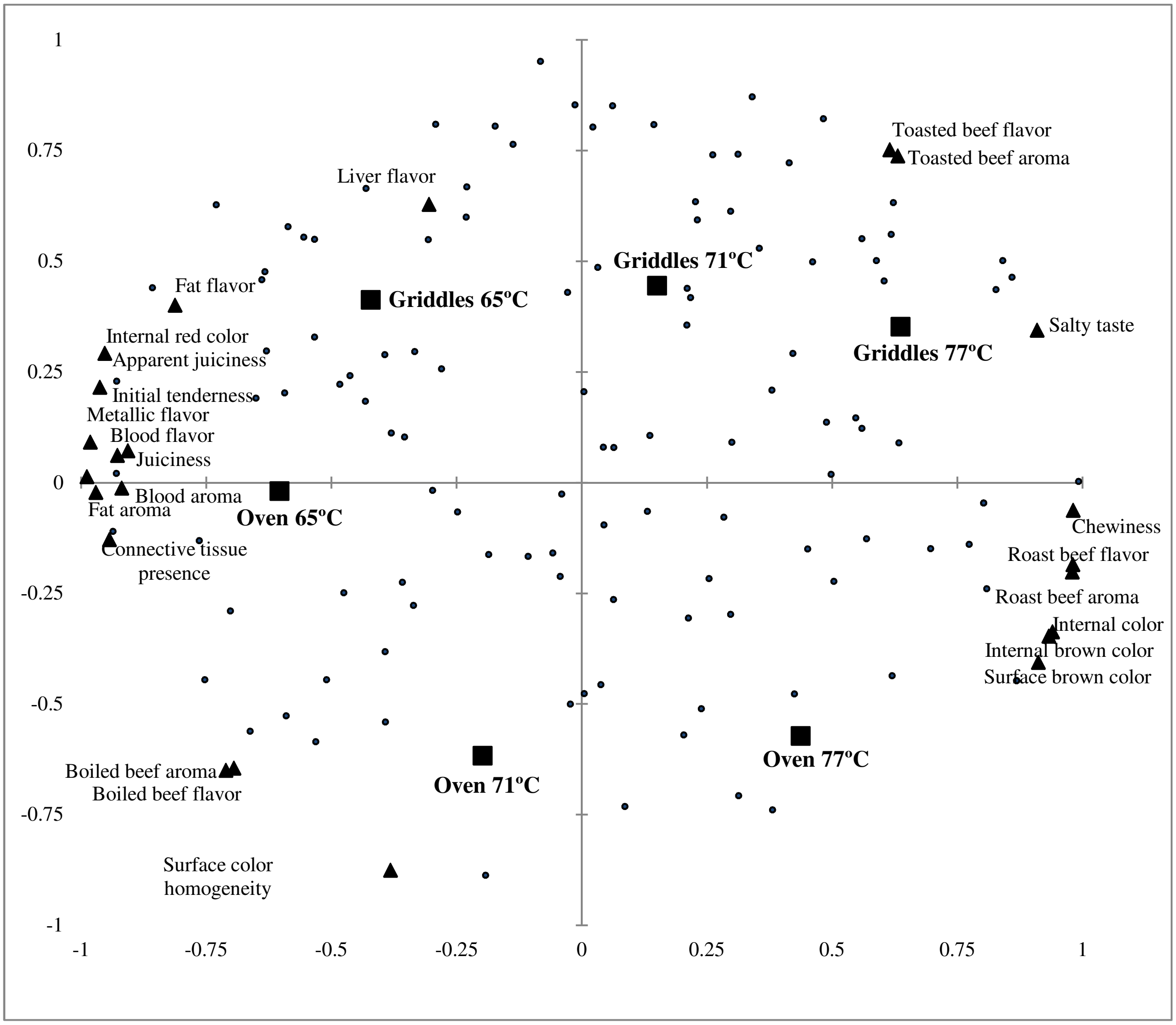

Figure 4. External preference map (X and Y are horizontal and vertical axes, respectively) obtained by partial least squares regression of descriptive data and respondent's overall liking scores for the sensory attributes of beef strip loin steak (square = samples; circle = consumers; triangle = attributes of quantitative descriptive analysis)

6. ARTIGO 2

<u>Artigo aceito para publicação</u>

Food Science and Technology

TEMPORAL CHANGES OF TENDERNESS AND JUICINESS OF BEEF STRIP LOIN STEAKS

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6.1. Abstract

The objective of this study was to determine the time-intensity curve profiles of beef strip loin steaks subjected to two cooking methods (oven and griddles) and three end-point temperatures (65, 71 and 77°C) for the tenderness and juiciness stimuli. The time-intensity analysis was performed with 12 trained assessors, and data collection was done on a computer using the software system – SCDTI (Time-Intensity Data Collecting System). The affective test, with just-about-right scale, for cooking degree and tenderness, was carried out with 118 consumers. The *Imax* values for tenderness and juiciness stimuli was higher ($P<0.05$) for the samples subjected to the electric oven as compared to the electric griddles. Regarding the temperatures, although the *Imax* for tenderness and juiciness of the samples subjected to temperatures of 65 and 71ºC were not different ($P>0.05$), it differed ($P<0.05$) from the samples at 77ºC. The *Ttot* value was not different ($P>0.05$) for both cooking methods and end-point temperatures in relation to the stimuli tenderness and juiciness. Regarding to affective test with just-about-right scale, the steaks subjected to electric griddles at 71°C were considered at the optimal degree of doneness, while the steaks subjected to electric griddles at 65° C exhibited ideal tenderness.

Keywords: time-intensity analysis, beef strip loin, cooking method, end-point temperature

6.2. Introduction

Different sensory stimuli display unique time courses of perception, from onset through maximum intensity to extinction. In some cases, the period of the persistence of a specific sensation may be an important factor (Ventanas, Puolanne & Tuorila, 2010).

In relation to meat products, texture is the most important sensory stimulus, and it plays an important role in consumer acceptance. Thus, the most important attributes for meat texture are tenderness and juiciness (Zimoch & Gullet, 1996; Butler, Posh, Mackie, & Jones, 1996).

According to Butler, Posh, Mackie, & Jones (1996) tenderness is a major sensory characteristic that varies during chewing. The perception of this attribute does not occur only at the first bite, but continues during chewing until the phase of swallowing. Moreover, the meat succulence persists throughout mastication until swallowing, when the stimulus is suddenly finished (Zimoch & Gullet, 1996).

Therefore, evaluating changes of tenderness and juiciness profile throughout this period (chewing until swallowing) is extremely important, and the determination of this intensity during the consumption can be performed with accurate way by computerized time-intensity analysis.

The time-intensity methodology is a type of descriptive analysis that allows one to verify changes in the perception of a particular attribute over time (Mcgowan & Lee, 2006). The sensory evaluation using time-intensity method is an extension of the classical scaling method providing temporal information about the perceived sensation (Cliff & Heymann, 1993).

Researchers have developed automated procedures for computerized time-intensity analysis using different tools and visual representations of the scales (Duizer, Gullett & Findlay, 1993). In Brazil, the SCDTI program (Time-Intensity Data Collecting System) is currently registered as TIAFT (Time-Intensity analysis of flavors and tastes) was developed at the Laboratory for Sensory Science and Consumer Studies, in Faculty of Food Engineering - UNICAMP (Bolini-Cardello et al., 2003; Palazzo & Bolini, 2014).

This sensory technique has been used to analyze many food matrices such as chocolates (Palazzo et al., 2011), ice creams (Cadena & Bolini, 2011), coffee (Moraes & Bolini, 2010), and raspberry-flavored gelatin (Palazzo & Bolini, 2009), demonstrating thus the importance of such techniques in sensory evaluation of foods. Regarding meat products, early studies that applied the time-intensity technique evaluated changes in meat tenderness during chewing (Butler, Posh, Mackie, & Jones, 1996; Zimoch & Gullet, 1996). Recently, Emrick, Penfield, Bacon, Van Laack & Breeke (2005) and Reinbach, Toft & Moller (2009) analyzed temporal flavor perception in chicken and pork patties, respectively. Saltiness perception was also studied in cured ham by time-intensity analysis (Bertram, Wu, Straddt, Aagaard & Anslyng, 2006) and the effect of fat and NaCL content on the dynamic perception of flavor and texture in flavored cooked bologna type sausages (Ventanas, Puolanne & Tuorila, 2010).

Use of the time-intensity profile as a tool for measuring juiciness and tenderness in beef samples subjected to different cooking methods and different end-point temperatures may bring important information for the research on food, thus contributing to improvements to obtain a product with particular texture characteristics according to the consumer's preferences.

Therefore, the aim of this study was to determine the time-intensity curve profiles of beef strip loin steaks subjected to two cooking methods (oven and griddles) and three end-point temperatures (65, 71 and 77°C) in relation to tenderness and juiciness stimuli, and to determine the ideal of tenderness and degree of doneness, using a just-about-right test.

6.3. Material and Methods

6.3.1. Meat samples

Strip loin samples (n=100) (m. *longissimus lumborum / NAMP 180)* with the same degree of fat thickness (6-10mm) from the 12^{th} rib to the second lumbar vertebra of the left side of the carcass, with similar age (USDA "A" maturity) Angus animals (Brazilian Certified Angus Beef) were collected three days *postmortem*. The subcutaneous fat was trimmed from these samples and the samples were vacuum packed and aged for 14 days (2 ºC). At the end of the aging period, the samples were frozen (-20 ºC). After freezing, each piece was cut (using a band saw) into six 2.54-centimeters thick steaks (perpendicular to the steak surface). The steaks remained frozen and were vacuum packed (Barrier bag BH620T, Sealed Air Inc. – Cryovac division, Duncan, SC) and frozen, commercial freezer (dark condition),until analysis. The following analyses were performed: Time-Intensity Analysis by trained assessors and a Just About Right test (JAR) by consumers.

6.3.2. Cooking process

The cooking procedures for the sensory evaluation followed the experimental protocol described by AMSA (1995) with adaptations. The six steaks, of the same strip loin, were distributed to six treatments in a 2x3 factorial arrangement, with two cooking methods (oven and griddles) and three end-point temperatures (65, 71 and 77°C). The distribution was carried out according to a balanced complete block design (always alternating the position of the steaks between treatments for reducing the effect generated by the steak position) (Macfie, Bratchell, Greenhoff & Vallis, 1989). Before cooking, the steaks were thawed at 4 °C for 24 hours and weighed.

The electric counter-top griddles (model CE 65; Power Fire Ldta., Rio de Janeiro, State of Rio de Janeiro-RJ, Brazil) were preheated for 30 minutes and the temperature was maintained between 150 and 170°C. To avoid prolonged contact of the steak surface with the griddles, the steaks were turned every 30 seconds for the first three minutes, then every minute until the specified end-point temperature (65, 71 and 77°C) was reached.

The conventional electric oven (model 45X60 – 3000 W; Fritomaq Ltda., São Paulo, SP, Brazil) was preheated for 30 minutes on the "high" setting, and the temperature was maintained between 130 and 150°C. The steaks were placed on a set consisting of a tray and aluminum grill. After the internal temperature reached its halfway point (32.5, 35.5 and 38.5°C), the steaks were turned so that they were cooked to a similar degree on both sides. The steaks remained in that position until the end-point temperature (65, 71 and 77°C) was reached; at this point, the steaks were removed from the oven.

For both cooking methods, the internal temperatures of the samples were monitored during cooking by copper-constantan thermocouples (Type T, Pyrotec Automação Ltda., Sousas, SP, Brazil) inserted into the geometric center of each steak, connected to a digital temperature indicator (Pyrotec Automação Ltda., Sousas, SP, Brazil).

6.3.3. Preparation and Presentation of the Samples

After cooking, the steaks were cut into cubes of 1.5 X 1.5 X steak thickness (centimeters), and placed in glass vessels within a yoghurt maker warmed at approximately 40 ºC. To evaluate the six samples of beef strip loin steaks, assessors received a beef cube per attribute (initial tenderness and initial juiciness) in a monadic way, served in a ramekin randomly coded with three-digit numbers on a porcelain dish heated to 50°C in electrical heater. The assessors were instructed to rinse their mouth with distilled water between samples.

6.3.4. Time Intensity Analysis

The time-intensity analysis was performed to evaluate the tenderness and juiciness of six samples of beef strip loin steaks. The attributes, initial tenderness and initial juiciness, were evaluated separately. The analysis was performed in individual cabins with air conditioning (22°C) and red light, in the Laboratory for Sensory Science and Consumer Studies. Approval for the study was obtained from the Ethics Committee of the University of Campinas, and all volunteers gave a written consent.

Pre-selection of assessor

Subjects were pre-selected by paired t-tests applied to Wald's sequential analysis (Meilgaard, Civille & Carr, 2007). The parameters used in the sequential analysis were: p=0.45 (maximum unacceptable ability), p1=0.70 (minimum acceptable ability), α=0.05 (likelihood of accepting a candidate without sensory acuity) and β=0.05 (likelihood of rejecting a candidate with sensory acuity). A meat product to paired t-tests was prepared and the difference in texture was tested for significance at the 0.1% level. Each evaluator performed the tests to sequential analysis with nine replicates. Thirty individuals who performed the paired t-tests, sixteen judges were pre-selected.

Training session

After discussion and consensus of all assessors, the references were determined and the training sessions were conducted with the attributes and references described in Table 1. A training was carried out, where each assessor was introduced to the computer system during an initial 10 minutes, one-on-one session, followed by 6 training sessions to become familiar with the program and movement of the mouse (Bolini Cardello & Faria, 1999; Bolini-Cardello, Silva &

Damásio, 1999; Bolini-Cardello, 2003). Each panelist was presented with a cube for assessing tenderness and a cube for assessing juiciness.

During the sessions, assessors hearing the first signal (10 seconds) given by the computer were instructed to place the beef cube between their posterior molar teeth, with the fibers perpendicular to the teeth. The assessment of juiciness and tenderness of the meat samples started at first bite until the phase of swallowing, and each assessor had 60 seconds to perform the analysis (Zimoch & Gullet, 1996).

Selection of Assessors

To select assessors, the six beef strip loin steak samples were evaluated in six repetitions for each stimulus in a monadic form following a balanced complete block design (Macfie, Bratchell, Greenhoff & Vallis, 1989). Analysis of variance (ANOVA), Two-way, with two source variation (sample and repetition) to each descriptor term and each assessor was applied and the assessors were chosen to participate according to their discriminating capability ($P<0.50$) and repeatability ($P>0.05$) using data collected during the training sessions; individual consensuses were also considered (Damásio & Costell, 1991). Twelve pre-selected panelists of sixteen (10 women and 2 men) were chosen to participate the final selection. An unstructured linear scale of 9 centimeters anchored with the words *less* on the left and *very* on the right (Stone, Bleibaum & Thomas, 2012; Meilgaard, Civille & Carr, 2007) appeared on the computer screen, once for each sample, to assess the maximum intensity perceived.

Data collection was performed on a computer using the software SCDTI (Bolini-Cardello et al., 2003), which assessed the data collected during each sensory evaluation session and furnished the following parameters: *Imax* (maximum intensity recorded by the assessor); *Timax* (time in which the maximum intensity was recorded); *Area* (area of the time curve X intensity) and *Ttot* (total duration time of the stimulus) (Palazzo & Bolini, 2009).

6.3.5. Just About Right (JAR)

One hundred and eighteen beef consumers over 18 years of age were recruited among students and staff at Unicamp to participate in the acceptance test. Those individuals who consumed beef at least once a week were considered beef consumers. Each meat sample was evaluated in a monadic way and according to a balanced complete block design (Macfie, Bratchell, Greenhoff & Vallis, 1989). The assessors were asked to evaluate how close to ideal the beef samples were in relation to the attributes tenderness and degree of doneness, using a 9 centimeters unstructured linear scale (Meilgaard, Civille & Carr, 2007) with anchors of "extremely less tender or less cooked than ideal on the left, "ideal tenderness and degree of doneness" on the middle, and "extremely tender or more cooked than ideal" on the right (Stone, Bleibaum & Thomas, 2012).

6.3.6. Statistical Analysis

Six steaks, from the same strip loin (experimental unit), were distributed to six treatments in a 2x3 factorial arrangement, with two cooking methods (oven and griddles) and three end-point temperatures (65, 7,1 and 77°C). It was evaluated six replications for each attribute of time intensity analysis.

The parameters obtained from the time-intensity curves were evaluated by analysis of variance (ANOVA): Two-way with two variations sources (assessor and sample) and means were compared by Tukey's test to investigate whether the samples differed at a 5% significance level using the Statistica 7.0 software (Statsoft, 2005). The results of the ideal profile analysis were expressed in a histogram of the responses (%) according to each attribute, indicating the percentage of assessors that marked the alternatives presented (Cadena & Bolini, 2011).

6.4. Results and Discussion

6.4.1. Stimulus Tenderness and Juiciness

Results from TI evaluations are show as means (±SEM) of the extracted TI parameters (Table 2) and as average TI-curves (Figure 2) for each attribute.

With regard to the *Imáx* (maximum intensity recorded by the assessor) values for tenderness, there was a significant interaction between cooking methods and end-point temperatures (P=0.003) (Table 2). The steak samples roasted in electric oven at 65 and 71°C exhibited similar *Imáx* values, which were higher than the values found at 77°C. Different behavior was observed for the samples grilled on electric griddles, exhibiting a higher *Imáx* value at 65°C, and lower *Imáx* values at 71 and 77°C (Figure 1). These results are evident in the Figure 2 (a), which shows the tenderness stimulus perceived by assessors for both cooking methods.

Our results are similar to Schmidt et al (2010), who studied tenderness intensity by descriptive sensory analysis, and found that choice steaks from bovine *Longissimus lumborum* muscle subjected at temperatures of 71 and 77°C did not differ (P>0.05), but were less tender (P<0.05) than steaks cooked at 66°C from those prepared in the electric oven. In the same way, Gomes, Pflanzer, Cruz, Felicio & Bolini (2014), found that the tenderness intensity of beef strip loin steaks roasted, both in the oven and on electric griddles, decreased tenderness as internal end-point temperature increased. Our results were different from Lorenzen, Davuluri, Adhikari & Grun (2005), who studied the tenderness intensity by descriptive sensory analysis of beef strip loin steaks submitted to open-hearth broiler, and found that samples submitted to 63, 71 and 77°C were not different (P>0.05).

Regarding to Imáx for juiciness stimulus, there was a difference (P<0.05) between the cooking methods for *Imax* values. Although no difference (P>0.05) was observed for the end-point temperatures of 65 and 71°C, they differed (P<0.05) from the samples at 77°C (Table 2). These results are evident in the Figure 2 (b), which shows the juiciness stimulus perceived by assessors for both cooking methods.

Our results are similar to Gomes, Pflanzer, Cruz, Felicio & Bolini (2014), the quantitative descriptive analysis showed that the juiciness of beef strip loin steaks cooked at 65 and 71°C in the oven, and grilled at 65°C on electric griddles was higher (P<0.05), and steaks roasted and grilled at 77°C had the lower (P<0.05) intensity of juiciness. In the same way, Lorenzen, Davuluri, Adhikari & Grun (2005), who studied the juiciness intensity by descriptive sensory analysis of beef strip loin steaks submitted to open-hearth broiler, found that samples submitted to 71 and 77°C had lower (P<0.05) juiciness scores than samples subjected to 63ºC.

Schmidt et al (2010), found that select steaks from bovine *Longissimus lumborum* muscle prepared in the electric oven subjected at temperatures of 66, 71 and 77°C did not differ (P>0.05) for juiciness intensity by descriptive sensory analysis. However, choice steaks from bovine *Longissimus lumborum* muscle, subjected at temperatures of 71 and 77°C presented higher juiciness (P>0.05) than steaks cooked at 66°C.

Based on the results of the present study, it may suggest that there was a tendency of *Imax* values for both stimuli tenderness and juiciness, i.e., the *Imax* values decreased as the internal temperature increased, which was similar to the results found in other studies (Bowers, Dikeman, Murray & Stroda, 2012; Gomes, Pflanzer, Cruz, Felicio & Bolini, 2014). Therefore, it can be stated that the steak samples roasted or grilled at lower temperatures scored higher for juiciness and tenderness than the steaks prepared at higher temperatures.

The time at which the stimulus is perceived in its plenitude (*Timax*) was not different ($P>0.05$) for both cooking methods and end-point temperatures of the stimulus tenderness and juiciness (Table 2).

The total duration time (*Ttot*) in which the stimulus is perceived is a differential obtained by the time-intensity analysis. The *Ttot* parameter was not different ($P>0.05$) for the cooking methods and end-point temperatures for the stimulus tenderness and juiciness (Table 2). Regarding *Ttot* values, different results were found by Zimoch & Gullet (1996), who evaluated the temporal difference between assessors in perception of juiciness and tenderness of roasted beef strip loin steaks (68°C). The authors concluded that the tenderness unlike juiciness persisted throughout chewing until swallowing the sample and then abruptly finished.

Although the time-intensity analysis of the current study was programmed to record the responses of the assessors up to 60 seconds, the evaluation of both stimuli tenderness and juiciness did not exceed 30 seconds. The results are lower than the values reported by Zimoch & Gullet (1996), who found values close to

40 seconds, indicating that the samples of this study required less time between chewing and swallowing.

According to the present results, it can be suggested that the differences on tenderness and juiciness found by the assessors were noted only at first bite (*Imax*). Perception of tenderness and juiciness during chewing to swallowing (*Ttot*) did not vary, showing that the samples may have not been influenced by changes in cooking method and end-point temperature, indicating that the samples remained homogeneous for both attributes after the first bite.

The area under the curve (Area) measured by a parameter enables the analysis of the general behavior of the sample. As this variable takes into account the initial time of the stimulus, the maximum intensity, and the time in which the stimulus is perceived, besides the time the assessor did not perceive the stimulus, it allows defining exactly the time-intensity profile of a product (Meilgaard, Civille & Carr, 2007).

For the parameter *Area* of the stimulus tenderness, differences (P<0.05) were observed between the cooking methods, and the highest average was found for the electric oven (Table 2). The temperatures of 65 and 71°C were not different (P>0.001), but differed (P<0.05) from the temperature of 77°C. For the parameter *Area* of the stimulus juiciness, there was difference (P<0.05) between cooking methods, with the highest average for the electric oven. The temperature of 65°C and 71°C were not different (P>0.001), but differed (P<0.05) from the temperature of 77°C.

Analyzing the general behavior of the samples, it can be suggested that both stimuli tenderness and juiciness analyzed by the assessors varied over time.

According to the results by Butler, Posh, Mackie, & Jones (1996), the stimulus tenderness for roasted pork, from two breeds (Hampshire and Yorkshire), prepared in an electric oven at three different temperatures (160, 170 and 180°C), changed ($P<0.05$) over time, however, the system did not require the assessors to initiate or finish their analysis at zero, different from our research, where the "typical" intensity curve described by Liu & Macfie (1990) starts at zero, increases over time and then returns to zero at the time or before a predetermined limit.

6.4.2. Just About Right (JAR)

Figure 3 shows the histograms of the frequency distribution of the affective test, with just-about-right scale, of tenderness and degree of doneness, in which consumers evaluated the ideal degree of doneness and tenderness of beef strip loin steaks. It can be noticed that the steaks submitted both to the oven as the griddles at 65°C had the lowest scores for ideal degree of doneness (56 and 62% respectively).

However, the samples grilled at 65°C had higher percentages of ideal tenderness, corresponding to 82%, followed by the samples submitted at 65 °C in the electric oven, with 70%.

Nevertheless, despite the electric griddles at lower temperature (65°C) had provided the highest scores for ideal tenderness, the lowest percentage (60%) was observed for the same treatment but at the highest temperature studied (griddles at 77ºC), together with the high percentage of degree of doneness (76%).

According to Chan, Moss, Farmer, Gordon & Cuskelly (2013), the beef sirloin steaks grilled in double-sided grill at 60 and 80ºC had higher percentages of ideal degree of doneness. According to Gomes, Pflanzer, Cruz, Felicio & Bolini (2014), who used to unstructured nine centimeters scale (1-disliked very much and 9-liked very much), steaks cooked and grilled in the oven and griddles at 65°C had the tendency to greater acceptable tenderness. Lorenzen, Davuluri, Adhikari & Grun (2005), used to structured nine centimeters scale, steaks cooked in the open-hearth broiler at 63°C had the tendency to greater acceptable tenderness. However, according to Gilpin, Batcher & Deary (1965) and Schmidt et at (2002) showed that rib and loin steak samples grilled at high temperatures received low scores for tenderness.

Thus, it can be seen that the temperature had a greater effect on the degree of doneness and tenderness of the samples, once the lowest temperature (65°C) for both cooking methods (oven and griddles) caused an impact on the ideal degree of doneness. However, a positive result was observed for the ideal tenderness, as reported by consumers.

6.5. Conclusions

The time-intensity analysis of the beef strip loin steaks subjected to two cooking methods (oven and griddles) and three end-point temperatures (65, 71 and 77°C) in relation to tenderness and juiciness stimuli, for the first time were reported. In this study, it is suggested that the differences on tenderness and juiciness found by the assessors were noted only at first bite. Perception of tenderness and juiciness during chewing to swallowing did not vary, showing that the samples may have not been influenced by changes in cooking method and end-point temperature, indicating that the samples remained homogeneous for both attributes after the first bite. However it affect the ideal perception of tenderness and degree of doneness, in which the griddles at 65ºC had the greater scores for tenderness, and griddles at 71 and 77ºC had the greater scores for degree of doneness.

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Table 1. Attributes used for the time-intensity analysis of beef striploin steaks.

Attributes	Definition	Reference
Initial Tenderness	Necessary force to bite (first bite) the meat sample using the molar teeth	***Less***: beef outside round (0.04X0.04X0.025m) roasted in electric oven (75°C) / ***Very***: beef tenderloin (0.025m) roasted in electric oven (65°C)
Initial Juiciness	Amount of liquid released during the first bite using the molar teeth	***Less***: beef outside round (0.04X0.04X0.025m) roasted in electric oven (75°C) / ***Very***: beef tenderloin (0.025m) roasted in electric oven (65°C)

Table 2. Mean values for both cooking methods and end-point temperature (±SEM) obtained from the time-intensity analysis. Significance level for cooking method (M), end-point temperature (T) and M-T interaction: *p < 0.05 and ***p < 0.001.

	Cooking Methods (M)		End-point Temperature (T)			Source of variation		
	Oven	Griddles	65ºC	71ºC	77ºC			
Tenderness						M	T	M - T
Imax	7.8 ± 0.11[#a]	7.3 ± 0.12[b]	8.1 ± 0.11[a]	7.7 ± 0.15[a]	6.9 ± 0.14[b]	***	***	***
Timax	6.0 ± 0.26	5.8 ± 0.21	5.5 ± 0.22	6.1 ± 0.31	6.1 ± 0.32	ns	ns	ns
Ttotal	27.0 ± 0.62	26.0 ± 0.58	26.9 ± 0.64	26.9 ± 0.82	25.7 ± 0.74	ns	ns	ns
Area	128 ± 3.82[a]	115 ± 3.75[b]	131 ± 4.02[a]	127 ± 4.85[a]	108 ± 4.86[b]	*	***	ns
Juiciness								
Imax	7.6 ± 0.12[a]	6.7 ± 0.13[b]	7.8 ± 0.14[a]	7.4 ± 0.14[a]	6.2 ± 0.17[b]	***	***	ns
Timax	6.8 ± 0.25	7.3 ± 0.29	6.9 ± 0.30	7.0 ± 0.33	7.2 ± 0.36	ns	ns	ns
Ttotal	27.8 ± 0.88	27.0 ± 0.87	28.4 ± 1.01	28.1 ± 1.05	25.6 ± 1.14	ns	ns	ns
Area	129 ± 5.53[a]	113 ± 5.22[b]	136 ± 6.44[a]	127 ± 6.68[a]	100 ± 6.38[b]	*	***	ns

Imax: maximum intensity recorded by the assessor; Timax: time in which the maximum intensity was recorded; Ttotal: total duration time of the stimulus; Area: area of the time curve X intensity; [#]Unstructured linear scale of 9 centimeters anchored with the words "*less*" on the left and "*very*" on the right.
[a, b] Means, in a row, with the same letter do not differ.

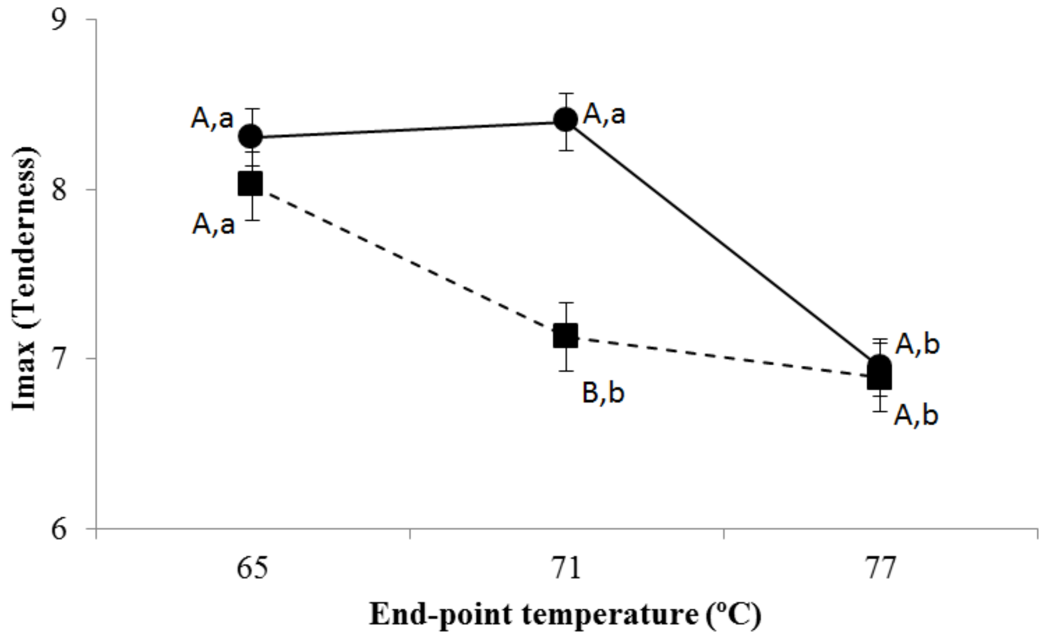

Figure 1. The relationship between cooking method and end-point temperature for Imax of tenderness (P = 0.003). [A,B] Means with the same letter for the same end-point temperature do not differ (P > 0.05). [a,b] Means with the same letter for the same cooking method do not differ (P > 0.05). Imax: maximum intensity recorded by the assessor. Unstructured linear scale of 9 centimeters anchored with the words "less" on the left and "very" on the right. —●— Oven; - -■- - Griddles.

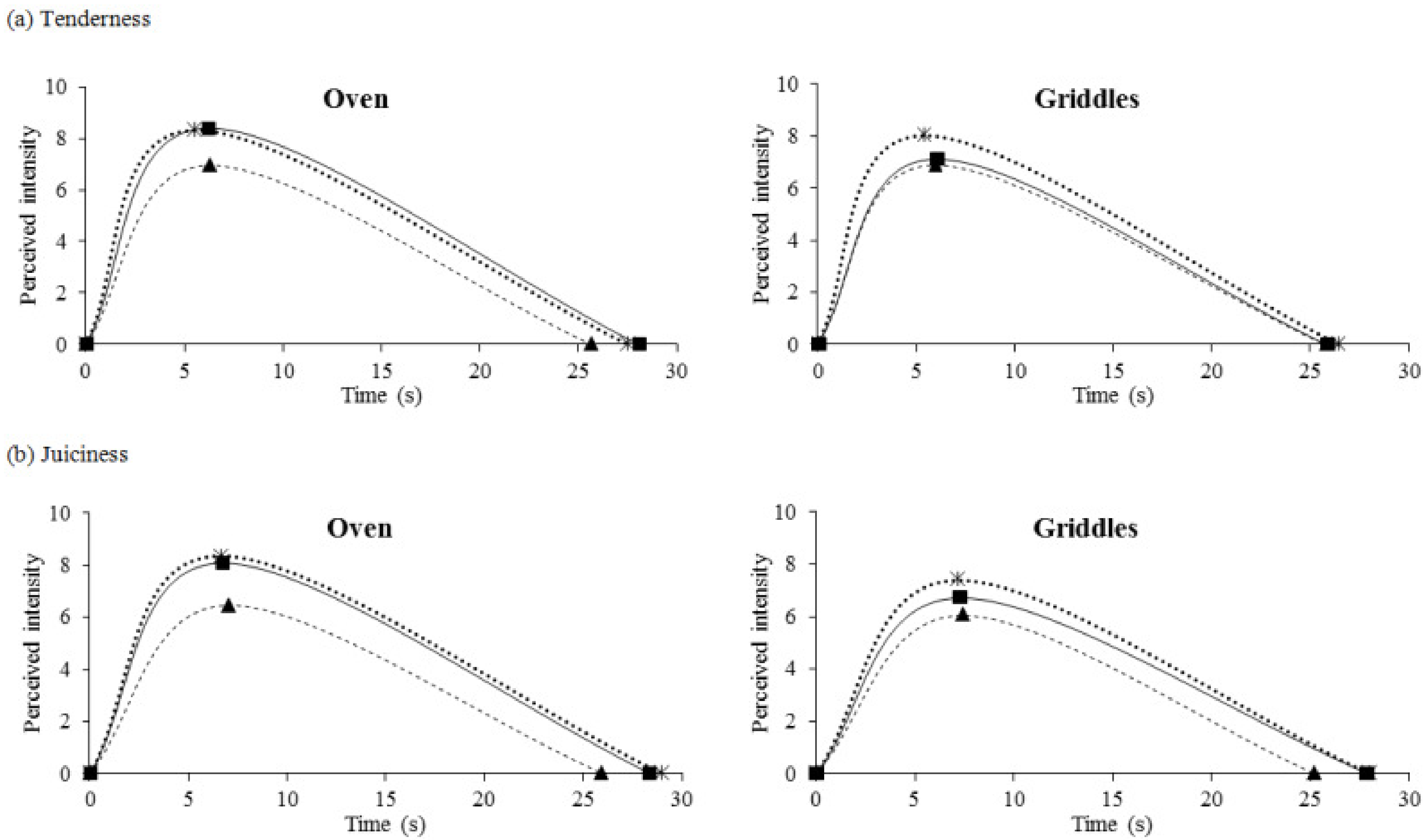

Figure 2. Average TI-curves for the attributes tenderness (a) and juiciness (b). Curves are sorted by cooking method. Unstructured linear scale of 9 centimeters anchored with the words "*less*" on the left and "*very*" on the right. ···✳··· 65ºC; —■— 71ºC; - -▲- - 77ºC.

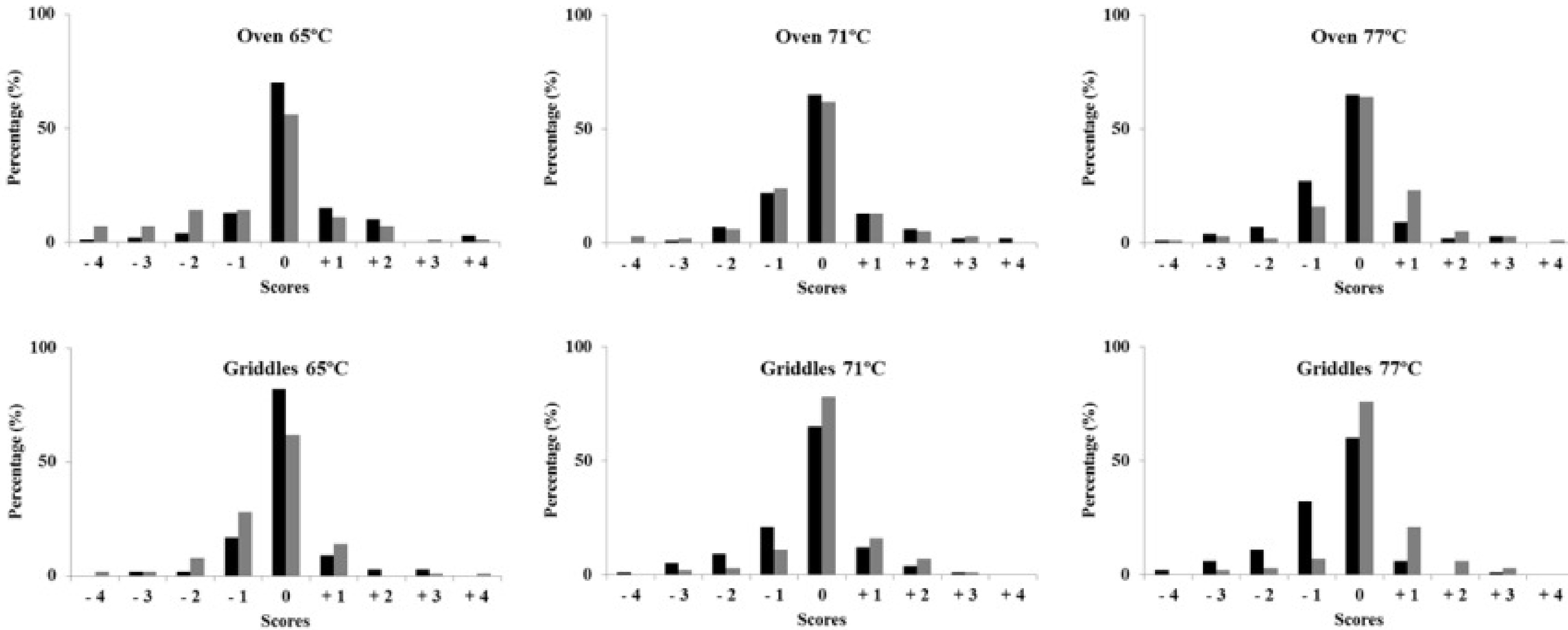

Figure 3. Histograms of distribution of samples of beef strip loin steaks in relation to the ideal of tenderness and degree of doneness. (- 4 = Extremely less tender or cooked than the ideal / - 3 = much less tender or cooked than the ideal / - 2= moderately less tender or cooked than the ideal / - 1 = slightly less tender or cooked than the ideal / = 0 ideal / 1 = slightly more tender or cooked than ideal / 2 = moderately more tender or cooked than ideal / 3 = much more tender or cooked than the ideal / 4 = extremely more tender or cooked than ideal). ■ Tenderness; ■ Degree of Doneness.

7. ARTIGO 3

Artigo formatado para publicação na *Meat Science*

CONSUMER PREFERENCE AND THE IMPORTANCE OF DESCRIPTIVE TERMS FOR DISCRIMINATING OF BEEF STRIP LOIN STEAKS

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7.1. Abstract

The objective of this study was to measure consumer acceptance and preference and to sort by order of importance the descriptive sensory profile terms used to discriminate beef strip loin steaks after cooking using two different methods (electric oven and counter-top griddles) to three end-point temperatures (65, 71 and 77 °C). Thirteen assessors measured the intensity of 23 descriptive terms using quantitative descriptive analysis (QDA), and their results were analyzed using stepwise discriminant analysis (SDA). Cluster analysis was also performed with consumers. In SDA, 15 descriptive terms were discriminated, and their order of importance was as follows: toasted beef aroma, degree of doneness, surface color homogeneity, surface brow color, internal red color, initial tenderness, cooked beef aroma, roast beef aroma, toasted beef flavor, blood flavor, salty taste, apparent juiciness, internal brown color, roast beef flavor and cooked beef flavor. Cluster analysis identified six consumer clusters. The largest clusters (1, 2, 4 and 5) consisted of a total of 108 (92%) consumers. Cluster 1 (36%) included the largest number of consumers and had the highest degree of acceptance for all of the samples compared with the other clusters. Conversely, Cluster 6 (2%) had the smallest number of consumers and likely included consumers who did not like any of the steaks based on their low acceptance scores.

Keywords: cluster analysis, preference mapping, stepwise analysis, beef strip loin, cooking method, end-point temperature

7.2. Introduction

Individual differences between consumers regarding their perception of meat palatability have been reported. These differences arise from the cooking method (Neely et al., 1999; Jeremiah, Gibson, Aalhus & Dugan, 2003) and the degree of doneness (the end-point temperature) to which the consumer likes to have his or her meat prepared (Lorenzen et al., 1999; Neely et al., 1999; Savell et al., 1999). Therefore, there is much information available on the impact of these factors on the consumer perception of meat palatability. However, there are no data that compare two cooking methods with three end-point temperatures and assess how the temperature influences consumer acceptance (Schmidt et al., 2010).

To better understand the variation of the consumer perception of several foods, cluster analysis has frequently been used, including in recent sensory analyses of meat products that examined deli ham (Wilbourn, Schilling, Martin, Coggins, & Armstrong, 2007), chicken breast (Battula et al., 2008), dry-cured ham (Pham et al., 2008) and beef strip loin (Schmidt et al., 2010).

Agglomerative hierarchical clustering is used in consumer-based tests because consumers have a range of tastes and preferences for food products (Schilling & Coggins, 2007). Cluster analysis is often applied to consumer data to help interpreting the results (Lawlor & Delahunty, 2000; Ares et al., 2006).

According to Carr (2004), end-point temperature affects the palatability of beef steaks, and consumer taste and preference for several food products vary. Therefore, cluster analysis may be able to group consumers by preference and taste for steak that is roasted or grilled using different cooking methods and prepared to different end-point temperatures.

Stepwise discriminant analysis (SDA) is a multivariate statistical method that orders variables or attributes according to their power to discriminate between samples (Bolini-Cardello, Silva & Damásio, 1999). Thus, it is effective in ordering descriptive terms from quantitative descriptive analysis because the method can discriminate between samples. This sensory technique has been used to analyze several food matrices, including commercial beer (Brown & Clapperton, 1978), frozen cheese (Alonso, Ramos, Martín-Alvarez & Juárez, 1987), cachaça (a hard liquor from sugar cane) with or without aging in oak barrels (Bolini-Cardello & Faria, 1999) and sweeteners/sucrose (Bolini-Cardello, Da Silva & Damásio, 1999).

The objective of this study was to determine consumer acceptance and preference and to order according to importance the terms (descriptors) of the descriptive sensory profile used to discriminate beef strip loin steaks cooked using two methods (electric oven and counter-top griddle) and three end-point temperatures (65, 71 and 77 °C).

7.3. *Materials and Methods*

7.3.1. *Steak Selection*

Strip loin samples (n=100) (m. *longissimus lumborum / NAMP 180)* with the same degree of fat thickness (6-10mm) from the 12^{th} rib to the second lumbar vertebra of the left side of the carcass, with similar age (USDA "A" maturity) Angus animals (Brazilian Certified Angus Beef) were collected three days *postmortem*. The subcutaneous fat was trimmed from these samples and the samples were vacuum packed and aged for 14 days (2 ºC). At the end of the aging period, the samples were frozen (-20 ºC).

7.3.2. *Sample Processing*

After freezing, each piece was cut (using a band saw) into six 2.54-centimeters thick steaks (perpendicular to the steak surface). The steaks remained frozen and were vacuum packed (Barrier bag BH620T, Sealed Air Inc. – Cryovac division, Duncan, SC) and frozen, commercial freezer (dark condition), until analysis. Then, the steaks were divided into six treatment groups, with two cooking methods (oven and griddles) and three end-point temperatures (65, 71 and 77 °C). The steaks were grouped using a balanced complete block design (always changing the position of the steaks between treatments to decrease position effects) (Macfie et al., 1989).

7.3.3. *Cooking*

Before cooking, the steaks were thawed at 4°C for 24 hours and weighed. The procedures for cooking the steaks and controlling the end-point temperature in the electric oven and on the counter-top griddle were conducted according to Gomes et al. (2014).

7.3.4. *Sample Preparation and Presentation*

After cooking, the steaks were cut into 1.5 X 1.5 X steak thickness (centimeters) and placed in labeled glass containers inside a yogurt maker heated to approximately 40 ºC.

In the quantitative descriptive analysis (QDA), the appearance was evaluated by the assessors using the entire steak, and the aroma, flavor and texture attributes, the assessors received two cubes of meat. For the acceptance analysis, the consumers received a single cube of meat per attribute. For both analyses, the cubes were served in a ramekin randomly labeled with a three-digit number on a porcelain plate heated to 50°C in an electric heater.

7.3.5. *Sensory Analyses*

Sensory analyses were performed in individual booths with temperature-controlled air (22°C) under white light. The analysis sessions were conducted in the Sensory Science and Consumer Research Laboratory at the Department of Food and Nutrition, School of Food Engineering (FEA/DEPAN) of the State University of Campinas. During the analyses, the testers/consumers were instructed to rinse their mouths with distilled water between samples. Approval for the study was obtained from the Ethics Committee of the University of Campinas, and written consent was provided by all of the volunteers.

7.3.6. *Stepwise Discriminant Analysis (SDA)*

The Quantitative Descriptive Analysis (QDA) was performed from the pre-selection of assessors to the analysis of data as published by Gomes et al

(2014). Thirteen assessors measured the intensity of 23 descriptive terms, the results were analyzed using SDA to determine the order of importance of the descriptive terms.

7.3.7. Acceptance Analysis

One hundred and eighteen beef consumers (47 male and 71 female aged between 18 and 30 years) were recruited to participate in the acceptance analysis. Each meat sample was evaluated monadically using a balanced complete block design (Macfie et al., 1989). Participants were asked to evaluate the acceptability of six beef strip loin samples based on their overall impression and using an unstructured 9 centimeters linear hedonic scale anchored with the terms "disliked very much" and "liked very much" (Stone, Bleibaum & Thomas, 2012; Meilgaard et al., 2007). Each consumer evaluated six beef strip loin samples during a single session.

7.3.8. Statistical Analysis

SDA was performed using the Statistical Analysis System (SAS) program (2013). The QDA data (Gomes et al., 2014) were analyzed using SDA to determine the order of importance of the descriptive terms used to discriminate meat samples. Principal component analysis (PCA) was performed using XLStat software (2011). The consumers were grouped according to their acceptance and preference for the two different cooking methods and three end-point temperatures using agglomerative hierarchical clustering based on Euclidean distance, with Ward's method as the aggregation criterion. Analysis of variance (ANOVA) and Tukey's test for the comparison of means were used to differentiate the samples ($P<0.05$)

between the treatments in each cluster using the SAS software (2013). An internal preference map (PREFMAP) was created to analyze acceptance of the consumers and the clusters using XLStat software (2011).

7.4. Results and Discussion

7.4.1. Stepwise Discriminant Analysis (SDA)

The table's second column presents the descriptive terms from the QDA in decreasing order of their ability to discriminate between samples cooked using two different methods and three different end-point temperatures (Table 1).

This analysis revealed the following order of importance of the descriptive terms: toasted beef aroma, degree of doneness, surface color homogeneity, surface brow color, internal red color, initial tenderness, boiled beef aroma, roast beef aroma, toasted beef flavor, blood flavor, salty taste, apparent juiciness, internal brown color, roast beef flavor and boiled beef flavor.

The descriptive terms that were not important for discriminating the samples were connective tissue presence, fat aroma, blood flavor, fat flavor, metallic flavor, liver flavor, juiciness and chewiness.

PCA (figure 1) was performed to compare the sensory characteristics of steaks roasted or grilled in the oven or on griddles. Principal Components I and II explained 98.43% of the sample variance. Moreover, the results indicated that the vectors with the greatest importance in the PCA were consistent with the most important descriptive terms in the SDA. It must be emphasized that PCA was performed using a single mean for the intensity of the descriptive terms as determined by the group of testers, unlike other studies that could consider each replicate for this representation (Gomes et al., 2014).

7.4.2. Cluster Analysis Preference and Liking

The mean overall impression of each cluster of beef strip loin (m. *longissimus lumborum)* from the six treatments is shown in Table 2.

The consumers were grouped into six clusters. The largest clusters (1, 2, 4 and 5) contained 108 (92%) consumers. Cluster 1 (36%) included the largest number of consumers and had a higher level of acceptance for all of the samples than the other clusters. There was no difference between treatments (P>0.05). Thus, the consumers did not differentiate between samples, which suggests that they liked all the samples.

Schilling and Coggins (2007) studied six chicken-nugget formulations that contained two types of flour (wheat or rice) using two different cooking methods (baking or frying). The consumers in Cluster 6 (18%) liked all of the nugget samples and had a higher degree of acceptance for all of the samples compared with the other clusters.

The consumers in Cluster 2 (18%) preferred (P<0.05) the grilled steaks to the roasted steaks for all end-point temperatures. The differences between temperatures for the same cooking method were not significant (P>0.05). In the Cluster 4 (22%) the steaks in oven at 77ºC and steaks in griddle at 65 and 71°C had a high degree of liking (P<0.05) than steaks in oven at 65ºC, however they did not differ (P>0.05) from steaks in oven at 71ºC and steaks in griddle at 77ºC. A similar trend was observed in Cluster 5 (16%), the steaks in oven at 77ºC and in griddle at 65ºC had a high degree of liking (P<0.05) than steaks at 71ºC in oven and griddle, but they did not differ (P>0.05) from steaks in oven at 65ºC and steaks in griddle at 77ºC.

Different results were reported by Schmidt et al. (2010) in a study on strip-loin steaks (select and choice) roasted in an electric oven to 60, 66, 71, 74 or 77°C. The consumer acceptability scores in the largest clusters decreased ($P<0.05$) as the end-point temperature increased.

Cluster 3 (6%) did not like ($P<0.05$) steaks in griddle at 77ºC, and prefer ($P<0.05$) steaks in oven at 65 and 71ºC. Cluster 6 (2%) contained the smallest number of consumers. There was not a difference between treatments ($P>0.05$), and the low acceptance scores of these consumers suggest that they did not liked the steaks.

Our results contradict these findings reported by Schilling & Coggins (2006). A total of 12% of the consumers in their Cluster 2 did not like any of the chicken-nugget treatments. Therefore, it is important to emphasize that the cluster of consumers that similarly did not like any of the six samples in our study represents only 2% of the research group.

Regarding the smallest clusters, Schmidt et al. (2010) found that the consumers in Cluster 1 (4%) preferred ($P<0.05$) beef strip loin steaks (choice) roasted in the oven to 60 °C and did not like steaks cooked to 71, 74 or 77 °C. In the same study, the consumers in Cluster 2 (3%) only did not like strip-loin steaks (select) roasted to 60°C, and Cluster 3 (3%) consumers did not like the steaks (select) roasted to 60 or 66°C.

The PREFMAP (Figure 2) shows the samples as points on the plot and the clusters as vectors. Principal Components I and II explained 88.15% of the sample variance. Clusters 2 and 4 are closer to the steaks cooked on the griddle to 71°C, showing more acceptance for those groups that sample, which is confirmed by the results shown in Table 2, where the consumers in these groups awarded higher scores to this sample. Cluster 3 is closest to the steaks cooked in the oven to 65°C, and Cluster 5 is closest to the steaks cooked on the griddle to 65°C. For these two groups, we can also see that the consumers awarded the highest scores to these samples. However, Clusters 1 and 6 are not close to any specific sample. This outcome is also confirmed by the results in Table 2, according to which these groups did not exhibit significant differences (P>0.05).

In the PREFMAP (Figure 3), consumers are represented by points in the vector space. A concentration of points near a particular sample suggests that the sample is more highly accepted. Based on our results, the distribution of the consumers is heterogeneous. Thus, to obtain a more accurate conclusion, the preference groups for each sample should be analyzed.

Based on this study's cluster analysis results, one can conclude that grouping consumers by preference and acceptance resulted in a better interpretation of consumer perceptions of steak than when using overall means.

In a Gomes et al. (2014), who evaluated overall acceptance using overall means, the highest score was attributed to beef strip-loin steaks cooked on a griddle to 65°C. This score was not different (P>0.05) from that of steaks cooked on a griddle to 71°C or in the oven to 77°C. However, the score was different from that for steaks roasted in an oven to 65°C. The steaks cooked on a griddle to 77°C and in the oven to 71°C were also not significantly different (P>0.05). In Lorenzen, Davuluri, Adhikari and Grun (2005), the overall acceptance of consumers for beef strip-loin steaks cooked in an open-hearth broiler to 55, 60, 63, 71, 77 and 82°C exhibited no significant difference.

7.5. Conclusions

Grouping consumers by preference and acceptance for two cooking methods and three end-point temperatures resulted in a better understanding of the perception of steak consumers than examining all of the consumers as a single group because a given consumer group (a cluster) may like a given sample, while another group rejects it.

Acknowledgments

The present study was performed with the support of the São Paulo Research Foundation (FAPESP) and the National Counsel of Technological and Scientific Development (CNPq).

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Table 1. Stepwise discriminant analysis - order of descriptors according to their discriminating power of beef strip loin steaks.

Steps	Included variable	R^2 partial	F statistical	Probability > F	Lambda de Wilks	Probability < λ
1	Toasted beef aroma	0.8179	414.88	0.0001	0.18214663	0.0001
2	Degree of doneness	0.7383	260.11	0.0001	0.04766762	0.0001
3	Surface color homogeneity	0.4133	64.80	0.0001	0.02796821	0.0001
4	Surface brown color	0.3637	52.47	0.0001	0.01779596	0.0001
5	Internal red color	0.1720	19.03	0.0001	0.01473463	0.0001
6	Initial tenderness	0.1520	16.38	0.0001	0.01249498	0.0001
7	Boiled beef aroma	0.1555	16.79	0.0001	0.01055250	0.0001
8	Roast beef aroma	0.1187	12.25	0.0001	0.00930032	0.0001
9	Toasted beef flavor	0.1216	12.57	0.0001	0.00816931	0.0001
10	Blood flavor	0.0955	9.56	0.0001	0.00738940	0.0001
11	Salty taste	0.0723	7.05	0.0001	0.00685485	0.0001
12	Apparent juiciness	0.0601	5.77	0.0001	0.00644299	0.0001
13	Internal brown color	0.0509	4.83	0.0003	0.00611478	0.0001
14	Roast beef flavor	0.0489	4.61	0.0004	0.00581593	0.0001
15	Boiled beef flavor	0.0485	4.56	0.0005	0.00553405	0.0001

R^2= Coefficient of Determination

F= Value given by the test MAHALANOBIS D^2

Table 2. Mean hedonic scores for overall acceptability of strip loin steaks cooked to different cooking methods and end-point temperatures according to different clusters of consumer segments.

Cooking method		Oven			Griddles		
Temperature (°C)		65	71	77	65	71	77
Cluster	Consumers (%)						
1	36	7.47^{a*}	7.70^{a}	7.68^{a}	7.56^{a}	7.53^{a}	7.56^{a}
2	18	5.65^{b}	5.79^{b}	5.90^{b}	7.57^{a}	7.98^{a}	7.45^{a}
3	6	6.67^{a}	6.60^{a}	4.37^{bc}	6.10^{ab}	4.25^{bc}	3.42^{c}
4	22	4.65^{b}	5.25^{ab}	5.70^{a}	5.94^{a}	6.00^{a}	5.25^{ab}
5	16	4.53^{ab}	3.66^{b}	4.84^{a}	5.32^{a}	3.75^{b}	4.26^{ab}
6	2	1.46^{a}	1.40^{a}	2.23^{a}	0.53^{a}	2.53^{a}	3.46^{a}

[a-c] Means within a row with the same superscript are not significantly different ($P > 0.05$)

*A linear hedonic scale unstructured of 9 centimeters anchored by words “disliked very much” and “liked very much”.

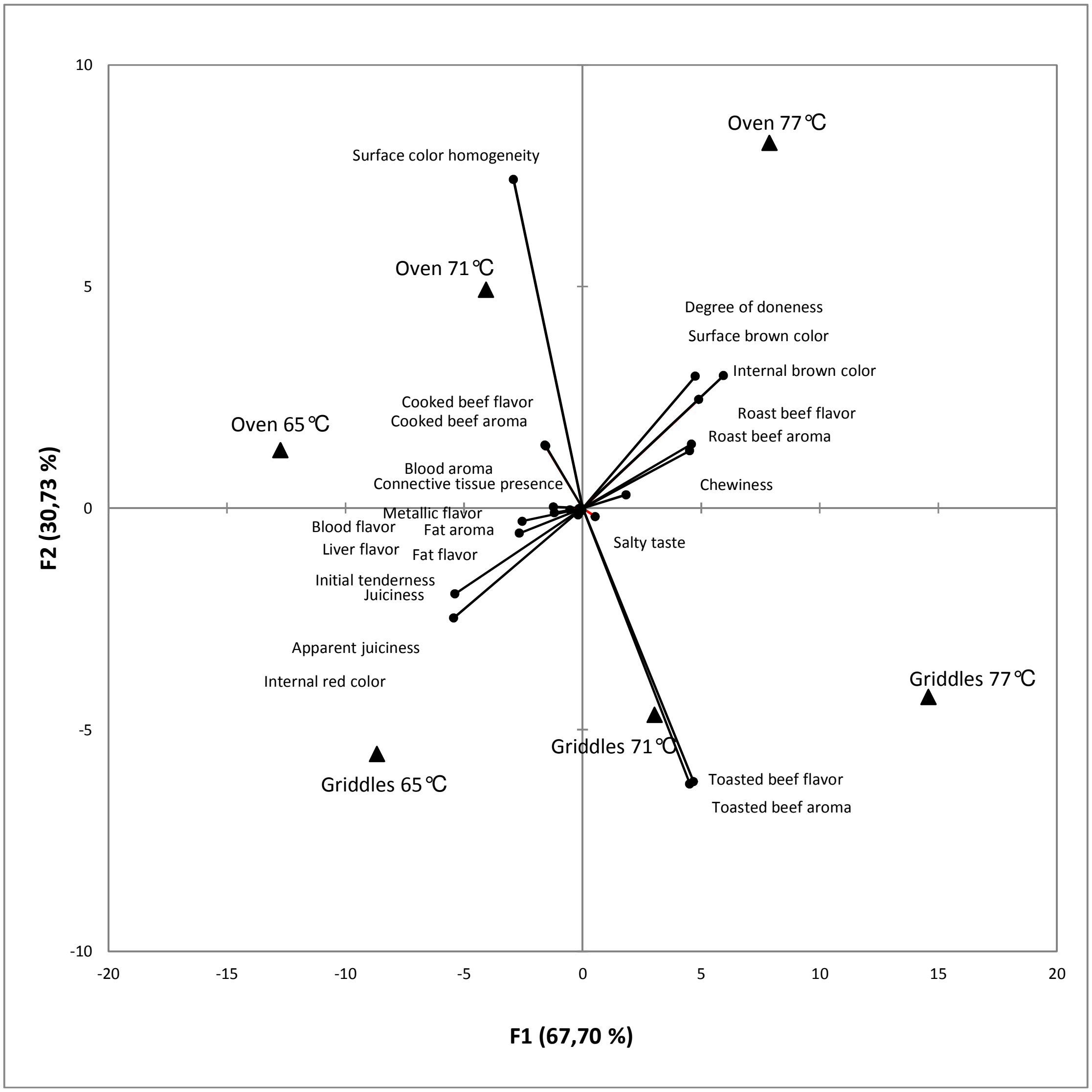

Figure 1. Principal components analysis of beef strip loin steaks

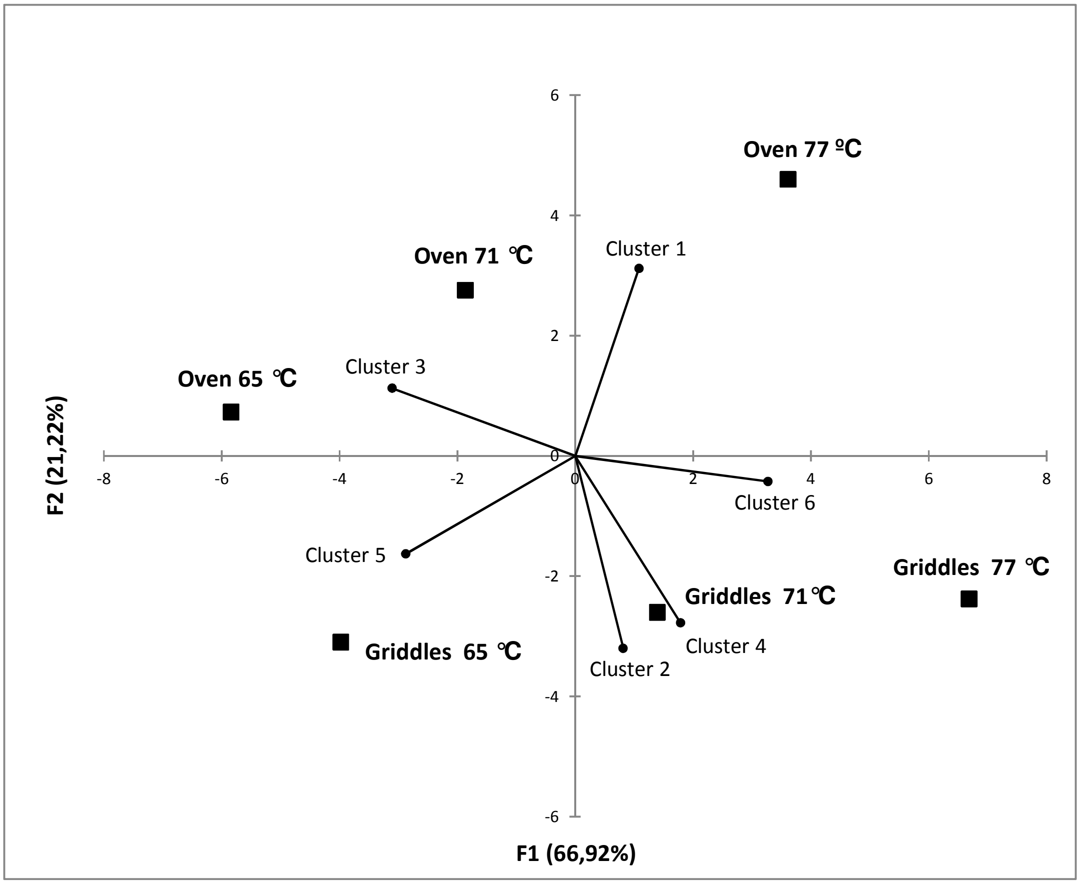

Figure 2. Internal Preference Map of beef strip loin steaks (square=samples and vectors/circle=clusters)

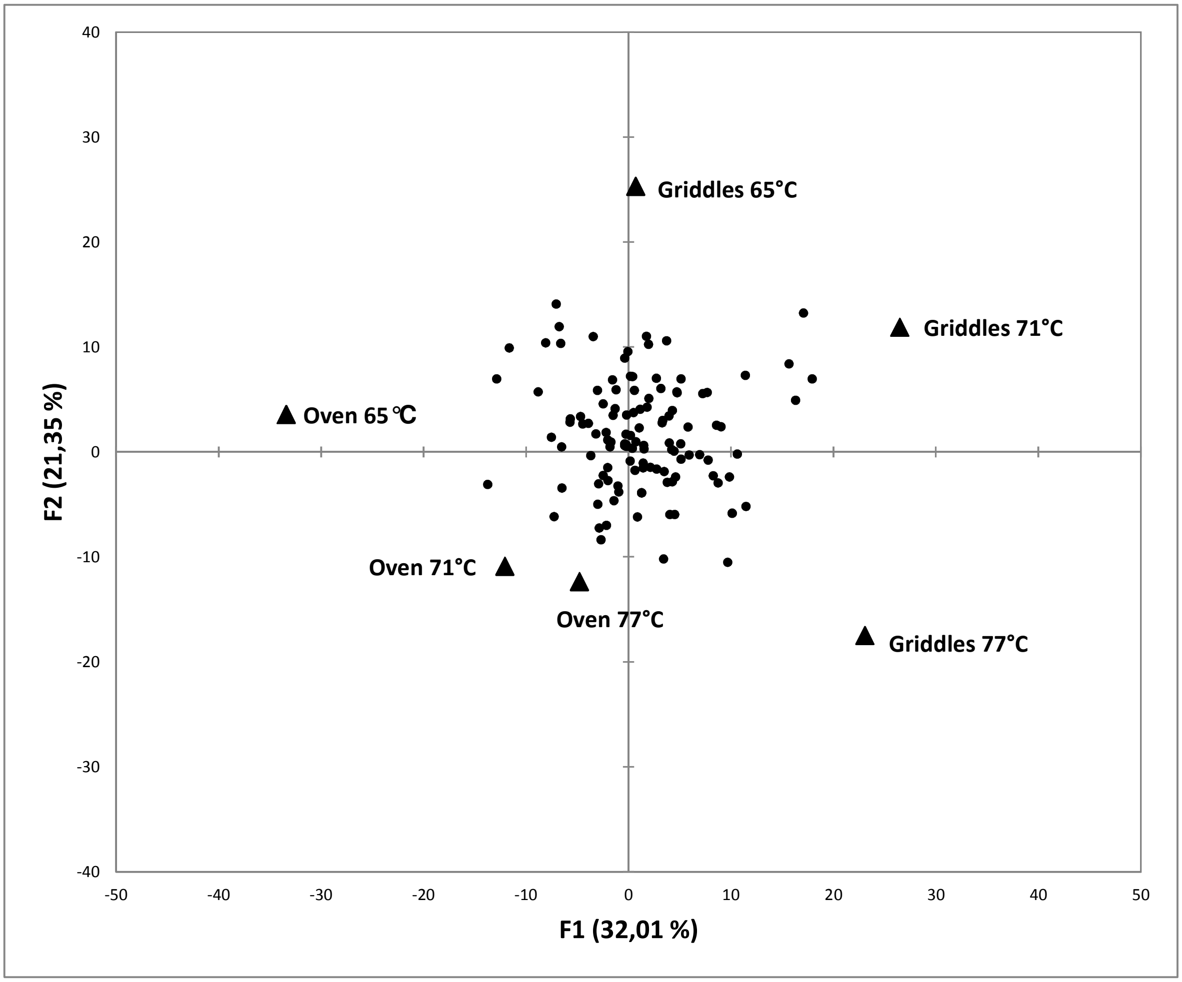

Figure 3. Internal Preference Map of beef strip loin steaks (triangle=samples and circle=consumers)

8. CONCLUSÃO GERAL

- Para a análise Descritiva Quantitativa, os bifes submetidos ao processo do forno e da chapa elétrica a 65°C foram caracterizados pelos os atributos de aroma e sabor de sangue, sabor metálico, suculência, maciez, suculência aparente e cor interna vermelha. Os bifes conduzidos no forno a 71°C foram caracterizados pelos descritores de aroma e sabor cozido e homogeneidade da cor da superfície. Já aqueles da chapa a 77°C foram caracterizados pelo aroma e sabor tostado. E os bifes submetidos no forno a 77°C foram caracterizados pelos atributos cor marrom da superfície, grau de cozimento, cor interna marrom e mastigabilidade.

- Para a análise de aceitação, a aparência, o aroma e o sabor tiveram maior aceitação nas amostras preparadas no forno elétrico em temperaturas mais altas, entretanto a maciez e a suculência tiveram maior aceitação nas amostras preparadas em temperaturas mais baixas, independente do método de cocção. Os bifes grelhados na chapa elétrica a 65°C foram melhores porque proporcionaram a obtenção de uma amostra com aceitação significativamente superior em relação a todas as características sensoriais analisadas.

- Na análise Tempo-intensidade pode-se sugerir que as diferenças encontradas para a maciez e suculência das amostras, foram percebidas somente a primeira mordida. As percepções de maciez e suculência durante a mastigação até a fase de deglutição não variaram, o que possivelmente revela que os bifes de contrafilé analisados no presente estudo não foram influenciados pelas alterações de método de cocção e temperatura interna final.

ANEXOS

Anexo 1. Parecer do Comitê de Ética do projeto de pesquisa

FACULDADE DE CIÊNCIAS MÉDICAS
COMITÊ DE ÉTICA EM PESQUISA

www.fcm.unicamp.br/fcm/pesquisa

CEP, 25/10/11
(Grupo III)

PARECER CEP: N° 1035/2011 (Este n° deve ser citado nas correspondências referente a este projeto).
CAAE: 0941.0.146.000-11

I - IDENTIFICAÇÃO:

PROJETO: **"IMPACTO DA TEMPERATURA FINAL INTERNA NOS DIFERENTES PROCESSOS DE TRANSFERÊNCIA DE CALOR EM PERFIL SENSORIAL DE CONTRAFILÉ BOVINO".**
PESQUISADOR RESPONSÁVEL: Carolina Lugnani Gomes
INSTITUIÇÃO: Faculdade de Engenharia de Alimentos/UNICAMP
APRESENTAÇÃO AO CEP: 05/10/2011
APRESENTAR RELATÓRIO EM: 25/10/12 (O formulário encontra-se no *site* acima).

II – OBJETIVOS.

Avaliar qual procedimento de preparação do contrafilé bovino proporciona a obtenção de um produto com perfil sensorial descritivo superior em relação a qualidade sensorial.

III – SUMÁRIO.

Não existem na literatura estudos com o perfil sensorial de maciez, sabor e suculência de carne bovina. Serão avaliados dois métodos de preparo de cocção (forno e *grill*) e em diferentes temperaturas internas. Amostras de contrafilé, embaladas a vácuo congeladas serão adquiridas. Serão realizadas análises sensoriais: análise descritiva quantitativa, análise tempo intensidade e análise de aceitação. Aproximadamente 30 candidatos da UNICAMP, consumidores de carne bovina serão convidados para fazerem parte da equipe de provadores treinados. Os critérios de inclusão estão demonstrados no projeto. Será realizada uma pré-seleção dos candidatos através da análise seqüencial de WALD.

IV - COMENTÁRIOS DOS RELATORES.

O projeto é simples na parte em que participam os sujeitos, uma vez que é análise sensorial de um produto já conhecido. O Termo de Consentimento Livre e Esclarecido está adequado.

V - PARECER DO CEP.

O Comitê de Ética em Pesquisa da Faculdade de Ciências Médicas da UNICAMP, após acatar os pareceres dos membros-relatores previamente designados para o presente caso e atendendo todos os dispositivos das Resoluções 196/96 e complementares, resolve aprovar sem restrições o Protocolo de Pesquisa, o Termo do Consentimento Livre e Esclarecido, bem como todos os anexos incluídos na pesquisa supracitada.

Comitê de Ética em Pesquisa - UNICAMP
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O conteúdo e as conclusões aqui apresentados são de responsabilidade exclusiva do CEP/FCM/UNICAMP e não representam a opinião da Universidade Estadual de Campinas nem a comprometem.

VI - INFORMAÇÕES COMPLEMENTARES.

O sujeito da pesquisa tem a liberdade de recusar-se a participar ou de retirar seu consentimento em qualquer fase da pesquisa, sem penalização alguma e sem prejuízo ao seu cuidado (Res. CNS 196/96 – Item IV.1.f) e deve receber uma cópia do Termo de Consentimento Livre e Esclarecido, na íntegra, por ele assinado (Item IV.2.d).

Pesquisador deve desenvolver a pesquisa conforme delineada no protocolo aprovado e descontinuar o estudo somente após análise das razões da descontinuidade pelo CEP que o aprovou (Res. CNS Item III.1.z), exceto quando perceber risco ou dano não previsto ao sujeito participante ou quando constatar a superioridade do regime oferecido a um dos grupos de pesquisa (Item V.3.).

O CEP deve ser informado de todos os efeitos adversos ou fatos relevantes que alterem o curso normal do estudo (Res. CNS Item V.4.). É papel do pesquisador assegurar medidas imediatas adequadas frente a evento adverso grave ocorrido (mesmo que tenha sido em outro centro) e enviar notificação ao CEP e à Agência Nacional de Vigilância Sanitária – ANVISA – junto com seu posicionamento.

Eventuais modificações ou emendas ao protocolo devem ser apresentadas ao CEP de forma clara e sucinta, identificando a parte do protocolo a ser modificada e suas justificativas. Em caso de projeto do Grupo I ou II apresentados anteriormente à ANVISA, o pesquisador ou patrocinador deve enviá-las também à mesma junto com o parecer aprovatório do CEP, para serem juntadas ao protocolo inicial (Res. 251/97, Item III.2.e).

Relatórios parciais e final devem ser apresentados ao CEP, de acordo com os prazos estabelecidos na Resolução CNS-MS 196/96.

VII – DATA DA REUNIÃO.

Homologado na X Reunião Ordinária do CEP/FCM, em 25 de outubro de 2011.

Prof. Dr. Carlos Eduardo Steiner
PRESIDENTE do COMITÊ DE ÉTICA EM PESQUISA
FCM / UNICAMP

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