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PROGRAMA DE PÓS-GRADUAÇÃO EM CIÊNCIA DE ALIMENTOS

LUIS ALFONSO BELTRÁN COTTA

EFEITO DA ADIÇÃO DE SUCO DE CAJÁ (*Spondias mombin* L.) NOS PARÂMETROS DE QUALIDADE DA CARNE SUÍNA

SALVADOR

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Dissertação apresentada ao Programa de Pós-Graduação em Ciência de Alimentos (PGAli) da Universidade Federal da Bahia, como requisito parcial para a obtenção do título de Mestre em Ciência de Alimentos.

Prof. Dr. Carlos Pasqualin Cavalheiro
Orientador

Prof. Dr. Marion Pereira da Costa
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TERMO DE APROVAÇÃO

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RESUMO

Esta pesquisa teve como objetivo avaliar o efeito do suco de cajá (*Spondias mombin L.*) como líquido de marinado sobre as propriedades de qualidade da carne de copa lombo suína durante a armazenagem em refrigeração. O suco de cajá foi utilizado como líquido de marinado em diferentes concentrações: 0% (C0), 50% (C50), 75% (C75) e 100% (C100) em amostras de copa lombo suína que foram analisadas quanto às propriedades tecnológicas, composição proximal e características sensoriais no dia 0 de armazenamento. Além disso, as análises de pH, oxidação lipídica, textura e microbiológica foram realizadas durante a armazenagem em refrigeração por 21 dias. Os resultados mostraram que o pH das amostras marinadas foi afetado pelo suco de cajá (P<0,05), com valores finais de 4,65 (C50), 4,56 (C75), e 4,39 (C100). Em relação às propriedades texturais, C75 e C100 tiveram os valores mais baixos de dureza e mastigabilidade durante o armazenamento. Por outro lado, o C100 teve os valores mais baixos contagens de mesofilos (5,69 log CFU g^{-1}), psicrófilos (7,10 log CFU g^{-1}), e Enterobacteriaceae (5,30 log CFU g^{-1}) que os outros tratamentos no final do armazenamento. Com relação às propriedades sensoriais, as amostras C50 e C75 foram as melhores amostras marinadas quanto à aceitabilidade e intenção de compra. Portanto, o uso de 75% de suco de cajá (C75) como líquido de marinado poderia ser uma alternativa viável para marinar a copa lombo suína.

Palavras-chave: Marinação de carne suína. Oxidação lipídica. Cor instrumental. Perfil de textura. Cajá.

ABSTRACT

This research aimed to evaluate the effect of yellow mombin (*Spondias mombin* L.) juice as a marinade liquid on the quality properties of Boston butt pork during refrigerated storage. Yellow mombin juice was used as a marinade liquid at different concentrations: 0% (C0), 50% (C50), 75% (C75), and 100% (C100) in Boston butt pork samples which were analyzed for technological properties, proximate composition, and sensory characteristics on day 0 of storage. In addition, the pH, lipid oxidation, textural, and microbiological analyzes were carried out during refrigerated storage for 21 days. The results showed that the pH of the marinated samples was affected by yellow mombin juice ($P<0.05$), with final values of 4.65 (C50), 4.56 (C75), and 4.39 (C100). Regarding the texture properties, C75 and C100 had the lowest values for hardness and chewiness during storage. In addition, C100 had the lowest mesophilic (5.69 log CFU g^{-1}), psychrophilic (7.10 log CFU g^{-1}), and Enterobacteriaceae (5.30 log CFU g^{-1}) counts that the other treatments at the end of storage. Regarding sensory properties, samples C50 and C75 were the best-rated marinated samples regarding acceptability and purchase intention. Therefore, the use of 75% yellow mombin juice (C75) as a marinade liquid could be a viable alternative for marinating Boston butt pork.

Keywords*: Pork marination. Lipid oxidation. Instrumental color. Texture profile. Cajá.*

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Capítulo I

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1 INTRODUÇÃO

O consumo global de carne tem aumentado constantemente nos últimos anos, atingindo um consumo de até 360 milhões de toneladas no século 21. Este aumento tem sido associado a uma população mundial crescente e ao aumento do consumo per capita (MANESSIS *et al.,* 2020). Por causa disso e da alta demanda por carne e produtos cárneos, as indústrias têm buscado métodos para tornar a conservação mais eficaz, além de atender às exigências de alta qualidade e segurança geral pretendidas pelos consumidores (KARAM *et al.,* 2019).

Os métodos de conservação de carne e produtos cárneos são muito diversos, incluindo tratamentos térmicos (congelamento, refrigeração, cozimento), tecnologias emergentes (aquecimento ôhmico, atmosferas modificadas) e a adição de conservantes, entre outros (PEREIRA; VICENTE, 2010; ZHOU; XU; LIU, 2010; RAHMAN *et al.,* 2018). A marinação é um dos métodos mais antigos utilizados na conservação de carne, que consiste em injetar ou imergir a carne em uma solução geralmente ácida (também chamada de líquido de marinação) e permitir que os componentes presentes no líquido se difundam na matriz alimentar por um determinado período de tempo (SINGH *et al.,* 2020). Além de aumentar a vida de prateleira das carnes, a marinação pode ter efeitos positivos nas propriedades físico-químicas, microbiológicas, sensoriais, tecnológicas e outras (BIANCHI *et al.,* 2009; RHOADES *et al.,* 2013; MOZURIENE *et al.*, 2016; TOLDRÁ, 2022).

Os líquidos de marinação comercial são geralmente compostos de água, polifosfatos, sais e antimicrobianos, entre outros ingredientes (GAO *et al.,* 2015a). No entanto, diversas pesquisas obtiveram resultados similares aos líquidos de marinação comerciais em carne bovina, suína e de frango, utilizando alternativas como o vinho (ARCANJO *et al.*, 2019; VASILIJEVIĆ *et al,* 2019), produtos lácteos (LATOCH; LIBERA; STASIAK, 2019; SIMITZIS *et al.,* 2021), vegetais (DEMIR; ÇELIK; SEZER, 2021) e especialmente frutas ricas em compostos bioativos (SENGUN; KILIC; OZTURK, 2019; POOONA *et al.*, 2020). Estas últimas, junto com a melhoria das propriedades sensoriais e físico-químicas, prolongam a vida de prateleira e utilizam ingredientes naturais que são exigidos pelos consumidores (BALASUNDRAM; SUNDRAM; SAMMAN, 2006; GÖK; BOR, 2016; LORENZO *et al.,* 2018).

O cajá (*Spondias mombin* L.) é uma fruta que podo ser usada para marinar carnes devido a seu baixo pH e aos muitos compostos bioativos que contém, tais como compostos fenólicos, β-caroteno e licopeno, tem é uma importante fonte de taninos, e vitaminas A e C, e boa capacidade antioxidante (MATTIETO, 2005 ;VASCO; RUALES; KAMAL-ELDIN, 2008;

TIBURSKI *et al*, 2011; MALDONADO-ASTUDILLO *et al.*, 2014; STAFUSSA et al., 2018; DE SOUZA *et al.*, 2020; OLADUNJOYE, *et al.*, 2021).

Apesar da crescente demanda por produtos cárneos marinados e dos efeitos positivos dos líquidos de marinação a partir do suco de frutas nos parâmetros de qualidade (YUSOP *et al.*, 2011; GÖK; BOR, 2016; SINGH *et al.*, 2020), não foi desenvolvida uma pesquisa utilizando frutas da região nordeste do Brasil, ricas em nutrientes, como o cajá. Portanto, esta pesquisa teve como objetivo avaliar o efeito de suco de cajá (*Spondias mombin* L.) nos parâmetros de qualidade de copa lombo suína durante o armazenamento.

2 OBJETIVOS

2.1 Objetivo geral

- ✓ Avaliar o efeito de suco de cajá (*Spondias mombin* L.) nos parâmetros de qualidade de copa lombo suína durante o armazenamento.

2.2 Objetivos específicos

- ✓ Avaliar as propriedades tecnológicas de copa lombo suína marinada em suco de cajá (*Spondias mombin* L.) y não marinada (controle);
- ✓ Avaliar as características físico-químicas de copa lombo suína marinada em suco de cajá (*Spondias mombin* L.) y não marinada (controle) durante o armazenamento;
- ✓ Estabelecer os parâmetros microbiológicos de copa lombo suína marinada em suco de cajá (*Spondias mombin* L.) y não marinada (controle) durante o armazenamento;
- ✓ Analisar as características sensoriais de copa lombo suína marinada em suco de cajá (*Spondias mombin* L.) y não marinada (controle).

3 FUNDAMENTAÇÃO TEÓRICA

3.1 Marinação

A marinação é uma das técnicas mais antigas utilizadas para a conservação de alimentos, utilizada principalmente para prolongar a vida útil do peixe, porém, tem sido utilizada em diferentes produtos (ovos, carne bovina, suína e aves) para melhorar suas características sensoriais, aumentar seu rendimento e capacidade de retenção de água, entre outros benefícios (TOLDRÁ, 2022; MOZURIENE *et al.*, 2016). A marinação consiste em adicionar líquidos, tais como vinagre, vinho, óleo, sucos de frutas, produtos lácteos fermentados, combinados com diferentes temperos, à carne antes de submetê-la a qualquer técnica de cozimento (SMITH; ACTON, 2010).

As duas formas mais comumente usadas para marinar são a imersão e o tumbling ou volteio. A marinação por imersão consiste em imergir a matriz alimentar em uma solução, marinada ou líquido de marinação, onde ela é mantida por um certo tempo. O líquido penetra no alimento através do mecanismo de difusão e gradualmente tende a um equilíbrio dinâmico (YUSOP *et al.*, 2010; SHI, 2023). Este não é muito utilizado na indústria devido ao tempo que pode levar para que o líquido de marinação penetre nos alimentos e porque não proporciona regularidade na distribuição dos ingredientes. Outro tipo de marinação é a marinação por tumbling, que consiste em adicionar a carne junto com o líquido de marinação em uma máquina de tumbling, onde ela permanecerá por um determinado tempo. Esta é a técnica mais utilizada na indústria de carnes porque facilita a penetração e distribuição do líquido de marinação (PIETRASIK; SHAND, 2003). O mecanismo aqui apresentado inclui a extração de proteínas miofibrilares na superfície da carne para melhorar a absorção de sal e aditivos (YUSOP et al., 2011).

Os ingredientes nos líquidos de marinação são muito importantes, pois de acordo com sua funcionalidade podem ser classificados de duas maneiras: 1) Ingredientes que influenciam a retenção de água e/ou propriedades texturais, através da força iônica e pH. Estes incluem vários fosfatos, ácidos orgânicos, hidrocoloides e enzimas, e 2) ingredientes que influenciam a escolha de compra do consumidor e a qualidade alimentar do produto. Estes incluem algumas ervas e temperos, extratos aromatizantes e adoçantes (TOLEDO, 2007).

3.1.1 Propriedades físico-químicas

3.1.1.1 Composição proximal

Na composição proximal dos produtos marinados, o parâmetro que pode ser mais comumente afetado é a umidade (com um aumento), e isto está relacionado com a absorção e retenção de água que ocorre neste processo. Pelo contrário, outros parâmetros como proteínas e cinzas podem ser reduzidos devido à lixiviação de proteínas sarcoplasmáticas no líquido de marinação e à redução de matéria seca do alimento (ARCANJO et al., 2019; POOONA; SINGH; PRABHAKARAN, 2019; SINGH et al., 2020; NOUR, 2022).

3.1.1.2 pH

O valor do pH das carnes marinadas dependerá em grande parte do pH do líquido de marinação. Na marinação são geralmente utilizados líquidos ácidos para melhorar várias características do produto final (BERGE et al., 2001; YUSOP et al., 2010). Outro fator que pode influenciar este parâmetro é o uso de produtos lácteos, que, tendo bactérias lácticas, causam a redução do pH da carne devido à produção de ácidos orgânicos produzidos por estas bactérias (GARGI; SENGUN, 2021).

Susanti *et al.* (2022), avaliaram o efeito do líquido de marinação de extrato de maçã na carne bovina, e observaram que o pH da matriz alimentar diminuiu significativamente com o aumento da concentração do extrato em até 20%. Esta diminuição no pH também foi evidenciada por Rupasinghe *et al*. (2022), ao utilizar sucos de frutas ricos em antioxidantes (manga, abacaxi, ameixa) como líquidos de marinação em asas de frango, mostrando valores de pH mais baixos durante todo o período de armazenamento em comparação com a amostra controle, indicando que o comportamento do pH pode ser devido à acidez dos sucos de frutas. Isto está de acordo com Unal *et al.* (2021) e Kumar *et al.* (2015) que atribuem a diminuição do pH ao teor de ácido orgânico em amostras de peito de frango marinadas com ácido cítrico, suco de limão e suco de toranja, e extrato de gengibre e suco de limão, respectivamente.

3.1.1.3 Oxidação lipídica

A oxidação lipídica é uma das principais causas de deterioração da carne durante o período de armazenamento, que é gerada pelos compostos tóxicos formados, incluindo espécies reativas de oxigênio, hidroperóxidos e radicais livres, e afeta negativamente o valor nutricional, a cor e o sabor do alimento (KIM *et al.,* 2013; NOUR, 2022). Este processo é influenciado principalmente pelo tempo, pois quanto mais tempo o produto é armazenado, maior a possibilidade de radicais causarem danos aos lipídios (DOMÍNGUEZ *et al.,* 2019). Um dos fatores que também pode estar envolvido na oxidação dos produtos de carne são os pró-oxidantes, tais como a mioglobina. Além disso, a aplicação de alguns processos na matriz alimentar, como o cozimento, pode ajudar esses agentes pró-oxidantes a entrar em contato com aquelas moléculas que provocam reações químicas oxidativas (GRAY; MONAHAN, 1992; GUYON; MEYNIER; LAMBALLERIE, 2016; RIBEIRO *et al.,* 2019). Entretanto, este efeito pode ser retardado na carne devido ao uso de produtos naturais com alta atividade antioxidante e teor de fenólicos totais para melhorar a estabilidade oxidativa dos lipídios (RUPASINGHE *et al.,* 2022).

Nour (2022), em sua pesquisa, marinou lombo suíno com suco de ameixa e ginja por 24 horas, avaliando a degradação lipídica durante 12 dias de armazenamento refrigerado. Aqui, os valores de substâncias reativas ao ácido tiobarbitúrico (TBARS) foram baixos, atribuindo isto aos compostos fenólicos e à atividade antioxidante contida nos sucos de frutas utilizados. Tal efeito também foi apresentado na carne bovina marinada com suco de cebola, apresentando valores de TBARS inferiores aos das amostras de controle, o que pode ser atribuído aos compostos antioxidantes presentes na cebola (ácido ferúlico, ácido gálico, ácido protocatecuico, quercetina e compostos organossulfurados), sendo um alimento rico nestes compostos (DEMIR; ÇELIK; SEZER, 2021).

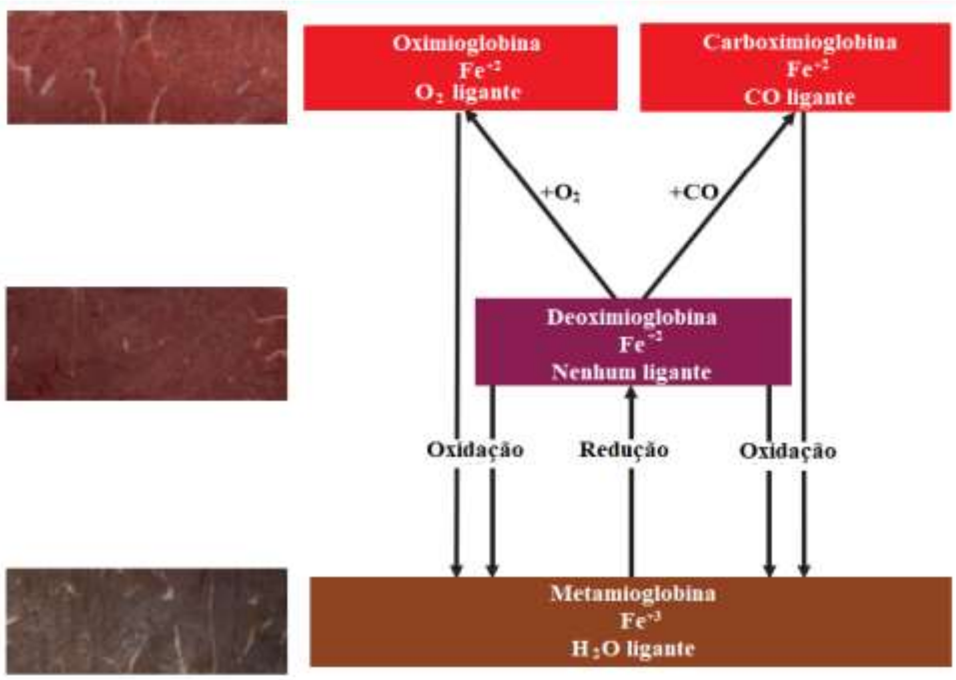
3.1.1.4 Cor

Embora a cor da carne não possa ser considerada um indicador confiável de sua qualidade, isto não impede que ela seja o aspecto que mais influencia a decisão de compra, pois esta propriedade representa a percepção de frescor do produto, o que é de grande importância para a indústria e os consumidores de carne (MANCINI; HUNT, 2005; TOMASEVIC *et al.*, 2021).

Quando a carne está em seu estado frescal, a mioglobina presente nela pode estar em qualquer um de seus estados redox: deoximioglobina, oximioglobina, carboximioglobina e metamioglobina (Figura 1) (MANCINI, 2013). Oximioglobina e carboximioglobina dão uma cor vermelho cereja brilhante à carne, muito relevante para a aceitação do consumidor (CORNFORTH; HUNT, 2008). A oximioglobina é um produto da saturação da mioglobina com oxigênio. A deoximioglobina é de cor vermelha arroxeada. A metamioglobina é o resultado da oxidação Fe^{+3}, que gera uma cor marrom na carne (SUMAN; JOSEPH, 2013).

Alguns processos como a refrigeração, congelamento, cozimento e marinação afetam a cor da carne. No processo de marinação, as matrizes utilizadas são sujeitas a tempos diferentes e entram em contato com líquidos de marinação que têm valores de pH diferentes. Líquidos de marinação com pH baixo (abaixo de 5) afetam visivelmente os valores de cor (principalmente aumentando os valores de luminosidade - *L**), pois podem causar desnaturação das proteínas musculares, o que causa maior reflexão de luz (YUSOP et al., 2010; 2012). Por outro lado, algumas pesquisas indicam que líquidos de marinação com pH acima de 9 diminuem os valores *L** (WOELFEL; SAMS, 2001; ALVARADO; SAMS, 2003). Além disso, quando os líquidos de marinação são ricos em pigmentos, mas com pH baixo, os valores *L** também diminuem (TKACZ et al., 2021).

Figura 1 − Efeitos do estado redox da mioglobina na cor da superfície do músculo post-mortem



Fonte: Mancini, 2013

O parâmetro vermelho – verde (a*) é o mais importante para a cor da carne e produtos cárneos. Valores elevados deste parâmetro na carne são inversamente proporcionais ao grau de desnaturação da mioglobina (LATOCH; LIBERA; STASIAK, 2019). Quando a matriz alimentar é marinada em um líquido de marinação rico em pigmentos naturais, os valores a* são aumentados (GÖK; BOR, 2016). Assim como a*, o aumento do parâmetro amarelo (b*) em carnes marinadas está associado à presença de pigmentos no líquido de marinação (SIROLI *et al.*, 2020).

3.1.1.5 Textura

Investigações diversas (ERGEZER; GOKCE, 2011; SHAREDEH *et al.*, 2015; LATOCH; LIBERA; STASIAK, 2019) mostraram que o uso de líquidos de marinação ácidos afetam as características texturais dos produtos marinados. Aqui, a redução do pH da carne pela ação do líquido de marinação pode diminuir a dureza do tecido muscular devido ao debilitamento das interações eletrostáticas que ocorrem entre as cadeias proteicas miofibrilares e o tecido conjuntivo, suavizando assim as proteínas do estroma (NOUR, 2022). A diminuição dos valores de dureza leva a valores de mastigabilidade mais baixos, o que ajuda a melhorar a percepção do consumidor sobre o produto final (GÖK; BOR, 2016).

3.1.2 Propriedades microbiológicas

A contaminação por micro-organismos é um resultado inevitável do processamento e armazenamento da carne. Portanto, a contagem de micro-organismos é importante para determinar o grau de frescor da carne e dos produtos cárneos. Nos produtos marinados, a eficácia dos líquidos de marinação contra o crescimento patógenos e contaminantes dependerá em grande parte do tipo de carne utilizada, pH do líquido de marinação (ácido ou alcalino) e dos ingredientes do líquido de marinação. Além da adição ou não de conservantes. Recentemente, óleos essenciais também foram utilizados na composição de líquidos de marinação por sua atividade antimicrobiana, mostrando resultados positivos (VASILIJEVIĆ *et al.*, 2019; KARAM *et al.*, 2020).

Alguns líquidos da marinação mostraram limitar a multiplicação de micro-organismos desfavoráveis. Isto se deve a seu pH, acidez, compostos fenólicos (presentes em frutas ou vegetais, ou bebidas alcoólicas à base destes) e à presença de cepas de bactérias lácticas (presentes em produtos à base de leite, como soro de leite e iogurte) que produzem substâncias com atividade antimicrobiana, como ácidos orgânicos e bacteriocinas (FADDA; LÓPEZ; VIGNOLO, 2010; GARGI; SENGUN, 2021; SOKOŁOWICZ *et al.*, 2021).

Pesquisas têm constatado que diferentes líquidos de marinação (com pH ácido, óleos essenciais, frutas, vegetais ou derivados de leite, entre outros) limitam o crescimento de micro-organismos como bactérias aeróbicas mesófilas, *Pseudomonas* spp, bactérias lácticas, enterobactérias, *Listeria monocytogenes*, bolores e leveduras, entre outras (ARCANJO *et al.*, 2019; VASILIJEVIĆ *et al.*, 2019; SOKOŁOWICZ *et al.*, 2021).

3.1.3 Propriedades tecnológicas

Além de ser utilizado a nível industrial e doméstico para melhorar as características sensoriais e prolongar a vida de prateleira dos produtos de carne, a marinação pode afetar positivamente as propriedades tecnológicas, especialmente a capacidade de retenção de água (WHC) (GAO *et al.*, 2015b). A WHC representa a quantidade de água retida no tecido após a pressão mecânica sobre o mesmo. Além disso, ajuda a determinar a aceitabilidade visual da carne, influenciando a decisão de compra do produto (SINGH; SHARMA, 2022; TOLDRÁ, 2022). Diversos estudos (RUPASINGHE *et al.*, 2022; SHI *et al.*, 2022; UNAL *et al.*, 2022) estabeleceram que o processo de marinação pode melhorar a capacidade de retenção de água de diferentes tipos de carne. Aqui, o líquido de marinada atinge as proteínas miofibrilares (actina, miosina e complexos de actomiosina), o que faz com que suas estruturas se liguem e retenham o líquido de marinação. Com base nisso, estudos indicam que as carnes bovinas permitem maior absorção de líquidos de marinação em comparação com carnes de aves (SENGUN; KILIC; OZTURK, 2020; SHI *et al.*, 2022).

A WHC está diretamente relacionada ao pH da carne, dado que a carne com um pH baixo terá um WHC mais baixo e um pH alto estará relacionado a uma WHC mais alta (BARBUT, 1993; HONIKEL et al., 1981), portanto, uma diminuição da WHC pode ocorrer na marinação durante a armazenagem devido à diminuição do pH, o que já foi evidenciado em estudos (RUPASINGHE *et al.*, 2022; SUSANTI *et al.*, 2022).

Em relação às perdas no cozimento, alguns pesquisadores (ONENC *et al.*, 2004; UNAL *et al.*, 2021) relatam que as carnes marinadas perdem menos água do que as não marinadas, este fenômeno está associado à acidez do líquido de marinação, que causa o inchaço das fibras, permitindo que as proteínas retenham mais água, levando a uma redução das perdas no cozimento (KLINHOM *et al.*, 2011).

3.1.4 Propriedades sensoriais

As características sensoriais da carne dependem de fatores físico-químicos, espécie animal, raça, idade, tipo de idade muscular, entre outros (VIŞAN et al., 2021). No entanto, a aplicação de técnicas de processamento, métodos de conservação (físicos ou químicos) ou tecnologias pode melhorar essas características (GÓMEZ; JANARDHANAN; IBAÑEZ; BERIAIN, 2020). A marinação tem sido considerada um método de conservação que, além de aumentar a vida de prateleira, melhora as propriedades sensoriais, como textura, aroma, sabor, entre outras (BHAT; MORTON; MASON; BEKHIT, 2018; SENGUN; TURP; CICEK; AVCI; OZTURK; KILIC, 2021). Em termos de cor, a marinação faz seja mais uniforme e na textura, proporciona mais maciez e suculência. Dentre os vários métodos de marinação, a marinação por tumbling tem os melhores resultados em termos de cor e sabor, devido à penetração mais eficiente e homogênea do líquido da marinação na matriz alimentar (YUSOP *et al.*, 2012). Quanto à marinação por imersão, quanto maior o tempo de marinação, maior é a aprovação em características sensoriais (GÖK; BOR, 2016).

O tempo de marinação também influencia as características sensoriais. Autores observaram que, ao comparar amostras marinadas, aquelas que tiveram um tempo de marinação mais longo apresentaram melhores resultados sensoriais gerais (GÖK; BOR, 2016; YUSOP *et al*., 2012). Isso está associado principalmente ao fato de que quanto maior o tempo de marinação, maior será a penetração e o efeito do líquido de marinação nos atributos sensoriais do produto.

A composição do líquido de marinação pode afetar positiva ou negativamente os parâmetros sensoriais da carne marinada (GARGI; SENGUN, 2021). Estes efeitos sobre a qualidade sensorial são devidos à presença de vários componentes como ácidos orgânicos (ácido cítrico, acético ou tartárico, os mais comuns), temperos, vinho, ervas, extratos, vegetais ou frutas, além de características destes como sua acidez, ajudam a melhorar a atratividade da carne marinada (O'NEILL *et al.*, 2019; YUSOP *et al*., 2011).

Uma tendência que surgiu nos últimos anos é o uso de sucos de frutas e vegetais para marinar diferentes tipos de carne. Sucos de frutas como kiwi, abacaxi, manga, ginja, toranja, limão e romã têm sido usados como líquidos de marinação, produzindo melhorias notáveis nos atributos sensoriais de aroma, sabor, cor, suculência e maciez (POOONA *et al*., 2020; UNAL; ALP; BABAOGLU; KARAKAYA, 2020; NOUR, 2022; RUPASINGHE *et al*., 2020; UNAL *et al*., 2022), esses resultados foram associados principalmente às características das frutas usadas. Essas pesquisas levaram à exploração de novas frutas para uso como líquidos de marinação.

3.2 Cajá

O cajá (*Spondias mombin* L.) é uma drupa elíptica de 3 a 5 cm de comprimento, com casca amarela a laranja, e sabor doce e azedo (Figura 2) (BOSCO *et al.*, 2000). É encontrado principalmente na estação chuvosa e está disponível por um curto período durante o ano. Provém de uma árvore que pertence à família Anacardiaceae e se encontra em várias zonas tropicais da África, América e Ásia; no Brasil está presente principalmente na região norte e nordeste (DE CARVALHO *et al.*, 2015).

Esta fruta tem substâncias bioativas, tais como compostos fenólicos (249 - 391,69 mg GAE/100 g) (DE SOUZA *et al.*, 2020, TIBURSKI *et al*, 2011; VASCO; RUALES; KAMAL-ELDIN, 2008), β-caroteno e licopeno (7,5 - 48,69 μg/g) (OLADUNJOYE *et al.*, 2021; MALDONADO-ASTUDILLO *et al.*, 2014), e é também uma importante fonte de taninos, e vitaminas A e C (MATTIETO, 2005). Além disso, tem capacidade antioxidante de 1271,88 μmol/100 g, 1352,23 μmol/100 g e 312,54 mmol Trolox/g determinada pelos métodos de DPPH, ABTS e ORAC, respectivamente (STAFUSSA *et al.*, 2018).

Figura 2 – Cajazeira (A) e cajá (B)

Fonte: elaboração própria

3.3 Carne suína

Por milhares de anos, a carne suína tem desempenhado um papel importante na dieta humana. A produção e o consumo desta fonte de proteína animal têm sido associados ao desenvolvimento da agricultura, quanto maior a produção agrícola, maior o consumo de carne suína (SZŰCS; VIDA, 2017).

O valor nutricional da carne suína pode ser associado aos principais nutrientes que ela possui, 1) seu teor proteico com aminoácidos essenciais, 2) a porcentagem de gordura (ácidos graxos saturados, monoinsaturados e poliinsaturados) que influencia positivamente suas características sensoriais, 3) vitaminas (vitaminas do grupo B), 4) minerais (ferro, zinco, selênio) e entre outros compostos como antioxidantes (LEBRET; ČANDEK-POTOKAR, 2021; ALFAIA *et al.*, 2019; HIGGS, 2000).

Segundo dados da Organização para Cooperação e Desenvolvimento Econômico (OCDE) (2023), a carne suína com 112,585 milhões de toneladas foi a segunda fonte de proteína animal mais consumida em 2022, atrás apenas do consumo de carne de aves com 133,696 milhões de toneladas. Globalmente, o principal consumidor foi a China (47,148 milhões de toneladas), seguido pelos Estados Unidos (10,213 milhões de toneladas), Rússia (3,922 milhões de toneladas) e Brasil (3,607 milhões de toneladas). Na América Latina, os maiores consumidores depois do Brasil foram México (2,451 milhões de toneladas), Argentina (681.000 toneladas), Colômbia (610.000 toneladas) e Chile (605.000 toneladas).

No Brasil, o consumo per capita dessa fonte de proteína vem aumentando desde 2010, quando foram consumidos 14 kg, para 16 kg em 2021, esse aumento está associado à melhor relação custo-benefício. Entre os estados com maior produção de carne suína em 2021 estão: Santa Catarina (1,11 milhões de toneladas), Rio Grande do Sul (730.079 toneladas), Paraná (677.184 toneladas), Minas Gerais (342.119 toneladas), Mato Grosso (221.143 toneladas) e Mato Grosso do Sul (193.985 toneladas) (EMBRAPA, 2022). Na região nordeste, o estado da Bahia foi o maior produtor com 19.683 toneladas (SOARES; XIMENES, 2022).

Na carne suína, a copa lombo (localizado parte frontal do lombo e acima das costelas) tem características sensoriais bastante interessantes, devido à sua suculência e marmorização. Apesar disso, este corte é pouco conhecido pelos consumidores. Portanto, dar valor agregado por meio da marinação seria de grande benefício para os consumidores e para a indústria.

REFERÊNCIAS

ALFAIA, C. M., *et al.* Current feeding strategies to improve pork intramuscular fat content and its nutritional quality. **Advances in food and nutrition research**, v. 89, p. 53-94, 2019.

ALVARADO, C. Z.; SAMS, A. R. Injection marination strategies for remediation of pale, exudative broiler breast meat. **Poultry Science**, v. 82, n. 8, p. 1332-1336, 2003.

ALVARADO, C.; MCKEE, S. Marination to improve functional properties and safety of poultry meat. **Journal of Applied Poultry Research**, v. 16, n. 1, p. 113-120, 2007.

ARCANJO, N. M. O., *et al*. Bioactivities of wine components on marinated beef during aging. **Journal of Functional Foods**, v. 57, p. 19-30, 2019.

BHAT, Z. F.; MORTON, J. D.; MASON, S. L.; BEKHIT, A. E. D. A. Applied and emerging methods for meat tenderization: A comparative perspective. **Comprehensive Reviews in Food Science and Food Safety**, v. 17, n. 4, 841-859, 2018.

BALASUNDRAM, N.; SUNDRAM, K.; SAMMAN, S. Phenolic compounds in plants and agri-industrial by-products: Antioxidant activity, occurrence, and potential uses. **Food chemistry**, v. 99, n. 1, p. 191-203, 2006.

BARBUT, S. Colour measurements for evaluating the pale soft exudative (PSE) occurrence in turkey meat. **Food Research International**, v. 26, n. 1, p. 39-43, 1993.

BERGE, P., *et al.* Tenderization of beef by lactic acid injected at different times post mortem. **Meat science**, v. 57, n. 4, p. 347-357, 2001.

BIANCHI, M.; PETRACCI, M.; CAVANI, C. The use of marination to improve poultry meat quality. **Italian Journal of Animal Science**, v. 8, n. 2, p. 757-759, 2009.

BOSCO, J.; SOARES, K. T.; AGUIAR FILHO, S. D.; BARROS, R. V. **A cultura da cajazeira**. João Pessoa, Brasil: EMEPA-PB, 2000.

CORNFORTH, D.; HUNT, M. Low-oxygen packaging of fresh meat with carbon monoxide. **AMSA white paper series**, v. 2, n. 10, p. 1-12, 2008.

DE CARVALHO, J. M., *et al.* Effect of processing on physicochemical composition, bioactive compounds and enzymatic activity of yellow mombin (Spondias mombin L.) tropical juice. **Journal of food science and technology**, v. 52, n. 2, p. 1182-1187, 2015.

DEMIR, H.; ÇELIK, S.; SEZER, Y. Ç. Effect of ultrasonication and vacuum impregnation pretreatments on the quality of beef marinated in onion juice a natural meat tenderizer. **Food Science and Technology International**, v. 28, n.4, p. 340-352, 2021.

DE SOUZA, V. R., *et al.* Fruit-based drink sensory, physicochemical, and antioxidant properties in the Amazon region: Murici (Byrsonima crassifolia (L.) Kunth and verbascifolia (L.) DC) and tapereba (Spondia mombin). **Food science & nutrition**, v. 8, n. 5, p. 2341-2347, 2020.

DOMÍNGUEZ, R., *et al.* A comprehensive review on lipid oxidation in meat and meat products. **Antioxidants**, v. 8, n. 10, p. 429, 2019.

EMBRAPA. Embrapa suínos e aves. Maiores produtores e exportadores, 2022. Disponível em: https://www.embrapa.br/suinos-e-aves/cias/estatisticas/suinos/brasil. Acesso em: 15 janeriro 2023.

ERGEZER, H.; GOKCE, R. Comparison of marinating with two different types of marinade on some quality and sensory characteristics of Turkey breast meat. **Journal of Animal and Veterinary Advances**, v. 10, n. 1, p. 60-67, 2011.

FADDA, S.; LÓPEZ, C.; VIGNOLO, G. Role of lactic acid bacteria during meat conditioning and fermentation: Peptides generated as sensorial and hygienic biomarkers. **Meat science**, v. 86, n. 1, p. 66-79, 2010.

GAO, T., *et al.* Effect of different tumbling marination methods and time on the quality characteristics of prepared pork chops. **Food Science and Technology**, v. 35, p. 445-451, 2015a.

GAO, T., *et al.* Effect of different tumbling marination methods and time on the water status and protein properties of prepared pork chops. **Asian-Australasian journal of animal sciences**, v. 28, n. 7, 1020, 2015b.

GARGI, A.; SENGUN, I. Y. Marination liquids enriched with probiotics and their inactivation effects against food-borne pathogens inoculated on meat. **Meat Science**, v. 182, p. 108624, 2021.

GÖK, V.; BOR, Y. Effect of marination with fruit and vegetable juice on the some quality characteristics of turkey breast meat. **Brazilian Journal of Poultry Science**, v. 18, p. 481-488, 2016.

GÓMEZ, I.; JANARDHANAN, R.; IBAÑEZ, F. C.; BERIAIN, M. J. The effects of processing and preservation technologies on meat quality: Sensory and nutritional aspects. **Foods**, v. 9, n.10, 1416, 2020.

GRAY, J. I.; MONAHAN, F. J. (1992). Measurement of lipid oxidation in meat and meat products. **Trends in Food Science and Technology**, v. 1, n. 3, p. 315-319, 1992.

GUYON, C.; MEYNIER, A.; LAMBALLERIE, M. (2016). Protein and lipid oxidation in meat: A review with emphasis on high-pressure treatments. **Trends in Food Science and Technology**, v. 50, p. 131-143, 2016.

HIGGS, J. D. The changing nature of red meat: 20 years of improving nutritional quality. **Trends in Food Science & Technology**, v. 11, n. 3, p. 85–95, 2000.

HONIKEL, K. O. *et al.* Influence of postmortem changes in bovine muscle on the water-holding capacity of beef. Postmortem storage of muscle at various temperatures between 0° and 30° C. **Journal of Food Science**, v. 46, n. 1, p. 23-31, 1981.

KARAM, L., *et al.* Antimicrobial effect of thymol and carvacrol added to a vinegar-based marinade for controlling spoilage of marinated beef (Shawarma) stored in air or vacuum packaging. **International Journal of Food Microbiology**, v. 332, p. 108769, 2020.

KARAM, L., *et al.* Combined effects of thymol, carvacrol and packaging on the shelf-life of marinated chicken. International journal of food microbiology, v. 291, p. 42-47, 2019.

KIM, H., *et al.* Synergistic effects of electron-beam irradiation and leek extract on the quality of pork jerky during ambient storage. **Asian-Australasian Journal of Animal Sciences**, v. 26, n. 4, p. 596, 2013.

KLINHOM, P., *et al.* Infuence of citric acid, lemon and porcupine fruit juice on the tenderness and sensory properties of bovine meat. **Agricultural Extension and Home Economics**, v. 4, n. 1, p. 1–10, 2011.

KUMAR, Y. *et al.* Augmentation of meat quality attributes of spent hen breast muscle (Pectoralis Major) by marination with lemon juice vis-a-vis ginger extract. **Journal of Animal Research**, v. 7, n. 3, p. 523, 2017.

LATOCH, A.; LIBERA, J.; STASIAK, D. M. (2019). Physicochemical properties of pork loin marinated in kefir, yoghurt or buttermilk and cooked sous vide. **Acta Scientiarum Polonorum Technologia Alimentaria**, v. 18, n. 2, p. 163-171, 2019.

LORENZO, J. M., *et al*. Berries extracts as natural antioxidants in meat products: A review. **Food Research International**, v. 106, p. 1095-1104, 2018.

MALDONADO-ASTUDILLO, Y. I., *et al*. Postharvest physiology and technology of Spondias purpurea L. and S. mombin L. **Scientia Horticulturae**, v. 174, p. 193-206, 2014.

MATTIETO, R. D. A. **Estudo Tecnologico de um Néctar Misto de Caja (Spondias lutea L.) e umbu (Spondias tuberosa, arruda camara)**. Tese (Doutor em Tecnologia de Alimentos) - Faculdade de Engenharia de Alimentos Universidade Estadual de Campinas. Campinas, 2005.

MANCINI, R. Meat color. *In:* Kert C.R. (ed). **The science of meat quality**. Oxford: Wiley-Blackwell, 2013. p. 177–199.

MANCINI, R. A.; HUNT, M. Current research in meat color. **Meat science**, v. 71, n. 1, p. 100-121, 2005.

MANESSIS, G., *et al.* Plant-derived natural antioxidants in meat and meat products. **Antioxidants**, v. 9, n. 12, p. 1215, 2020.

MATTIETTO, R. A.; MATTA, V. M. Cajá (Spondias mombin L.). *In*: Yahia E. M. (Ed). **Postharvest biology and technology of tropical and subtropical fruits**. Sawston: Woodhead Publishing, 2011. p. 330-351.

MOZURIENE, E., *et al*. Effect of natural marinade based on lactic acid bacteria on pork meat quality parameters and biogenic amine contents. **LWT-Food science and technology**, v. 69, p. 319-326, 2016.

NOUR, V. Effect of sour cherry or plum juice marinades on quality characteristics and oxidative stability of pork loin. **Foods**, v. 11, n. 8, p. 1088, 2022.

OECD. Meat consumption (indicator). 2023. Disponível em: https://data.oecd.org/agroutput/meat-consumption.htm. Acesso em: 19 janeiro 2023.

O'NEILL, C. M., *et al.* Comparative effect of different cooking methods on the physicochemical and sensory characteristics of high pressure processed marinated pork chops. **Innovative food science & emerging technologies**, v. 54, p. 19-27, 2019.

ÖNENÇ, A.; SERDAROĞLU, M.; ABDRAIMOV, K. Effect of various additives to marinating baths on some properties of cattle meat. **European Food Research and Technology**, v. 218, n. 2, p. 114-117, 2004.

OLADUNJOYE, A. O., *et al.* Effect of thermosonication on quality attributes of hog plum (Spondias mombin L.) juice. **Ultrasonics sonochemistry**, v. 70, p. 105316, 2021.

PEREIRA, R. N.; VICENTE, A. A. Environmental impact of novel thermal and non-thermal technologies in food processing. **Food Research International**, v. 43, n. 7, p. 1936-1943, 2010.

PIETRASIK, Z.; SHAND, P. J. The effect of quantity and timing of brine addition on water binding and textural characteristics of cooked beef rolls. **Meat Science**, v. 65, n. 2, p. 771-778, 2003.

POOONA, J.; SINGH, P.; PRABHAKARAN, P. Effect of kiwifruit juice and tumbling on tenderness and lipid oxidation in chicken nuggets. **Nutrition & Food Science**, v. 50, n. 1, p. 74-83, 2020.

RAHMAN, U., *et al.* Advanced meat preservation methods: A mini review. **Journal of food safety**, v. 38, n. 4, p. e12467, 2018.

RHOADES, J., *et al.* Use of marination for controlling Salmonella enterica and Listeria monocytogenes in raw beef. **Food microbiology**, v. 36, n. 2, p. 248-253, 2013.

RIBEIRO, J. S. *et al.* Natural antioxidants used in meat products: a brief review. **Meat Science**, v. 148, p. 181-188, 2019.

RUPASINGHE, R. A. *et al.* Oxidative stability of vacuum-packed chicken wings marinated with fruit juices during frozen storage. **Food Science of Animal Resources**, v. 42, n. 1, p. 61, 2022.

SENGUN, I. Y.; KILIC, G.; OZTURK, B. The effects of koruk products used as marination liquids against foodborne pathogens (Escherichia coli O157: H7, Listeria monocytogenes and Salmonella Typhimurium) inoculated on poultry meat. **LWT-Food science and technology**, v. 133, p. 110148, 2020.

SENGUN, I. Y.; TURP, G. Y.; CICEK, S. N.; AVCI, T.; OZTURK, B.; KILIC, G. Assessment of the effect of marination with organic fruit vinegars on safety and quality of beef. **International Journal of Food Microbiology**, v. 336, 108904, 2021.

SHAREDEH, D., *et al.* Effects of pH and NaCl levels in a beef marinade on physicochemical states of lipids and proteins and on tissue microstructure. **Meat science**, v. 110, p. 24-31, 2015.

SHI, H., *et al.* Evaluation of ultrasound-assisted L-histidine marination on beef M. semitendinosus: Insight into meat quality and actomyosin properties. **Ultrasonics sonochemistry**, v. 85, p. 105987, 2022.

SHI, Y., *et al*. Simulation of diffusion behavior of NaCl in multi-tissue beef marination process. **Food Chemistry**, v. 402, p. 134164, 2023.

SIMITZIS, P., *et al.* A Note on the Effects of Yoghurt Acid Whey Marination on the Tenderness and Oxidative Stability of Different Meat Types. **Foods**, v. 10, n. 11, p. 2557, 2021.

SINGH, K.; SHARMA, N. Physical and biochemical changes in ultra-rapid air chilled broiler muscle and quality of marinated chicken breast filets. **Food Bioscience**, v. 46, p. 101524, 2022.

SINGH, P., *et al.* Effect of vacuum tumbling and red beetroot juice incorporation on quality characteristics of marinated chicken breast and leg meats. **Nutrition & Food Science**, v. 50, n. 1, p. 143-156, 2020.

SIROLI, L., *et al.* Use of essential oils to increase the safety and the quality of marinated pork loin. **Foods**, v. 9, n. 8, p. 987, 2020.

SMITH, D. P.; ACTON, J. C. Chapter Marination, cooking, and curing of poultry products. *In*: Casey M. Owens (Ed). **Poultry Meat Processing**. Boca Raton: CRC Press, 2010. p. 323-348.

SOARES, K.; XIMENES, L. Carne Suína. **Caderno Setorial ETENE**, v. 7, n. 221, p. 1-12, 2022.

SOKOŁOWICZ, Z., *et al.* Technological and Sensory Quality and Microbiological Safety of RIR Chicken Breast Meat Marinated with Fermented Milk Products. **Animals**, v. 11, n. 11, p. 3282, 2021.

STAFUSSA, A. P., *et al.* Bioactive compounds of 44 traditional and exotic Brazilian fruit pulps: phenolic compounds and antioxidant activity. **International Journal of Food Properties**, v. 21, n. 1, p. 106-118, 2018.

SUMAN, S. P.; JOSEPH, P. Myoglobin chemistry and meat color. **Annual review of food science and technology**, v. 4, n. 1, p. 79-99, 2013.

SUSANTI, S. *et al.* Physical and chemical characteristics of beef marinated by cashew apple extract. **International Journal of Food Studies**, v. 11, n. 1, 2022.

SZŰCS, I.; VIDA, V. Global tendencies in pork meat-production, trade and consumption. **Applied Studies in Agribusiness and Commerce**, v. 11, n. 3-4, p. 105-111, 2017.

TIBURSKI, J. H., *et al.* Nutritional properties of yellow mombin (Spondias mombin L.) pulp. Food Research International, v. 44, n. 7, p. 2326-2331, 2011.

TKACZ, K., *et al.* Improving the quality of sous-vide beef from Holstein-Friesian bulls by different marinades. **Meat Science**, v. 182, p. 108639, 2021.

TOLDRÁ, F. **Lawrie's meat science**. 9º ed. Cambridge: Woodhead Publishing, 2022.

TOLEDO, R. T. Overview of marination technology, advances in marination science & technology. The University of Georgia, Amerika, 2007.

TOMASEVIC, I., *et al*. Recent advances in meat color research. **Current Opinion in Food Science**, v. 41, p. 81-87, 2021.

UNAL, K., *et al.* Marination with citric acid, lemon, and grapefruit affects the sensory, textural, and microstructure characteristics of poultry meat. **British Poultry Science**, v. 63, n. 1, p. 31-38, 2022.

UNAL, K.; ALP, H.; BABAOGLU, A. S.; KARAKAYA, M. Different properties of chicken and turkey breast fillets marinated with fruit juices. **Fleischwirtschaft**, v. 100, n. 2, p. 88-93, 2020.

VASILIJEVIĆ, B., *et al*. Antibacterial effect of Juniperus communis and Satureja montana essential oils against Listeria monocytogenes in vitro and in wine marinated beef**. Food control**, v. 100, p. 247-256, 2019.

VASCO, C.; RUALES, J.; KAMAL-ELDIN, A. Total phenolic compounds and antioxidant capacities of major fruits from Ecuador. **Food chemistry**, v. 111, n. 4, p. 816-823, 2008.

VIŞAN, V. G., et al. Influence of marination with aromatic herbs and cold pressed oils on black angus beef meat. **Foods**, v. 10, n. 9, 2012, 2021.

WOELFEL, R. L.; SAMS, A. R. (2001). Marination performance of pale broiler breast meat. **Poultry Science**, v. 80, n. 10, p. 1519-1522, 2001.

YUSOP, S. M., *et al.* Effect of marinating time and low pH on marinade performance and sensory acceptability of poultry meat. **Meat science**, v. 85, n. 4, p. 657-663, 2010.

YUSOP, S. M., *et al.* Influence of processing method and holding time on the physical and sensory qualities of cooked marinated chicken breast fillets. **LWT-Food Science and Technology**, v. 46, n. 1, p. 363-370, 2012.

YUSOP, S.M.; O'SULLIVAN, M.G.; KERRY, J.P. Marinating and enhancement of the nutritional content of processed meat products. *In*: Kerry, J.P.; Kerry, J.F. (Eds). **Processed Meats: Improving Safety, Nutrition and Quality**. 1ª ed. Philadelphia: Woodhead Publishing Limited. 2011; pp. 422–449.

ZHOU, G. H.; XU, X. L.; LIU, Y. Preservation technologies for fresh meat–A review. **Meat science**, v. 86, n. 1, p. 119-128, 2010.

Capítulo II

Manuscrito: Use of yellow mombin (Spondias mombin L.) juice in marination: Effect on quality properties of Boston butt pork during refrigerated storage

Use of yellow mombin (*Spondias mombin* L.) in marination: Effect on quality properties of Boston butt pork during refrigerated storage

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Abstract

This research aimed to evaluate the effect of yellow mombin (*Spondias mombin* L.) juice as a marinade liquid on the quality properties of Boston butt pork during refrigerated storage. Yellow mombin juice was used as a marinade liquid at different concentrations: 0% (C0), 50% (C50), 75% (C75), and 100% (C100) in Boston butt pork samples which were analyzed for technological properties, proximate composition, and sensory characteristics on day 0 of storage. In addition, the pH, lipid oxidation, textural, and microbiological analyzes were carried out during refrigerated storage for 21 days. The results showed that the pH of the marinated samples was affected by yellow mombin juice (P<0.05), with final values of 4.65 (C50), 4.56 (C75), and 4.39 (C100). Regarding the texture properties, C75 and C100 had the lowest values for hardness and chewiness during storage. In addition, C100 had the lowest mesophilic (5.69 log CFU g^{-1}), psychrophilic (7.10 log CFU g^{-1}), and Enterobacteriaceae (5.30 log CFU g^{-1}) counts that the other treatments at the end of storage. Regarding sensory properties, samples C50 and C75 were the best-rated marinated samples regarding acceptability and purchase intention. Therefore, the use of 75% yellow mombin juice (C75) as a marinade liquid could be a viable alternative for marinating Boston butt pork.

Keywords: Pork marination, lipid oxidation, color parameters, texture profile, cajá.

1. Introduction

Marinating is a preservation method that has historically been used to extend the shelf life of meat and improve its sensory properties, yield, and water retention, among others. This method consists of adding liquids containing spices, flavors, and functional ingredients, by injecting or immersing meat before cooking (Mozuriene et al., 2016).

Consumers demand meat and meat products with natural ingredients that guarantee their health and food quality. For this reason, various plant origins have emerged as an increasingly attractive option compared to traditional preservatives and synthetic components (Gómez, Janardhanan, Ibañez, & Beriain, 2020). Recently, fruit juices such as kiwi (Pooona, Singh, & Prabhakaran, 2020), grape (Sengun, Goztepe, & Ozturk, 2019), mango, pineapple (Rupasinghe, Alahakoon, Alakolanga, Jayasena, & Jo, 2022), sour cherry and plum (Nour, 2022), and vegetables such as onion, garlic (Kim et al., 2010), ginger (Kaewthong, Wattanachant, & Wattanachant, 2021), and beetroot (Singh, Yadav, Pathera, & Sharma, 2020) have already been used as marinade liquids in beef, pork, and chicken to extend shelf life. Moreover, these fruit juices also are applied to improve texture and sensory properties, inhibit microbial spoilage, reduce lipid oxidation, increase water-holding capacity, and more.

Yellow mombin (*Spondias mombin* L.), also known as cajá, hobo, or jobo, is a popular fruit grown in the northeastern region of Brazil but is also found in other countries in the Americas, Africa, and Asia (Tiburski, Rosenthal, Deliza, Godoy, & Pacheco, 2011). Studies have found that yellow mombin contains bioactive compounds, such as phenolic compounds (249 - 391.69 mg GAE 100 g^{-1}) (de Souza et al., 2020, Tiburski et al., 2011), β-carotene and lycopene (7.5 - 48.69 μg g^{-1}) (Oladunjoye, Adeboyejo, Okekunbi, & Aderibigbe, 2021; Maldonado-Astudillo et al., 2014) and is also an important source of tannins and vitamins A and C (Mattieto, Lopes, & Menezes, 2007). In addition, its antioxidant capacity is 1271.88 μmol 100 g^{-1}, 1352.23 μmol 100 g^{-1}, and 312.54 mmol Trolox g^{-1}, according to DPPH, ABTS, and ORAC assays, respectively (Stafussa et al., 2018).

Pork is a rich source of several nutrients in the human diet, such as protein, fat, vitamins (thiamine, riboflavin, and niacin), and minerals (iron, calcium, and magnesium) (Li et al., 2013). Due to this and its sensory properties, pork became the second most consumed protein globally in 2022 (OECD, 2023). Boston butt (*M. subscapularis*) pork is a juicy cut due to its marbling. Some studies already used different marinade liquids (including fruit juices) for pork meat (Cho, Kim, Kwon, Kim, & Jang, 2021; Siroli et al., 2020; Linares, Garrido, Martins, & Patarata, 2013). However, there are no studies on the benefits of yellow mombin juice as a marinade liquid in pork. Therefore, this research aimed to evaluate the effect of yellow mombin juice as a marinade liquid on the quality properties of Boston butt pork during refrigerated storage.

2. Materials and methods

2.1. Raw material

Fresh Boston butt pork and commercial frozen pulp of yellow mombin were obtained from a local market (Salvador, Brazil). Both the pork meat and yellow mombin pulp were frozen at -18 ºC until use.

2.2. Boston butt pork preparation and marination

Four different treatments of marinated Boston butt pork were prepared (in duplicate) and replicated on two different days. A non-marinated sample (C0) was used as a control, and three marinade liquids were prepared as follows: 50% yellow mombin pulp mixed with 50% water (C50), 75% yellow mombin pulp mixed with 25% water (C75), and 100% yellow mombin pulp (C100). Boston butt pork was cut into 1 cm thick slices weighing 125 ± 15 g. For marinating, the samples were immersed in plastic containers containing the marinade liquids and stored at 4 °C for 20 h. Subsequently, the samples were vacuum-packed using a vacuum sealer (model CELUX01-20; Electrolux, China) and stored at 4 °C for 21 days for analysis (Fig. 1).

2.3. *Cooking process*

Boston butt pork samples were cooked for 9 min (turning every minute) on an electric grill (PGR03P, Philco, São Paulo, Brazil) until the internal temperature reached 72 ºC.

2.4. Marinade liquid uptake, water holding capacity, and cooking loss

Marinade liquid uptake (MLU) was determined in triplicate, as described by Fadiloğlu and Serdaroğlu (2018). Boston butt pork (three per treatment) was weighed before and after the marination process, and the percentage of MLU was calculated as follows:

$$MLU\ (\%) = \left(\frac{Marinated\ weight - Non\ marinated\ weight}{Non\ marinated\ weight}\right) x\ 100$$

Water-holding capacity (WHC) was determined by compression (Hamm, 1961), in which 3 g of Boston butt pork samples (three per treatment) were placed between two sheets of filter paper (10 × 10 cm2; Whatman #1) and pressed between two acrylic plates. The set was pressed for 5 min with a weight of 10 kg. Then, the samples were weighed again and the WHC value was calculated as follows:

$$WHC\ (\%) = \left(\frac{Initial\ weight - Final\ weight}{Initial\ weight}\right) x\ 100$$

To evaluate cooking loss (CL), Boston butt pork samples (three per treatment) were weighed and cooked (as 2.3 section). Samples were then cooled to room temperature and reweighed. CL was calculated as follows (Yusop, O'Sullivan, Kerry, & Kerry, 2010):

$$CL\ (\%) = \left(\frac{Raw\ weight - Cooked\ weight}{Raw\ weight}\right) x\ 100$$

2.5. Physicochemical properties

2.5.1. Proximate composition

Proximate composition of Boston butt pork samples was measured in triplicate according to the AOAC (2005) methods for moisture (950.46), protein (981.10), fat (945.16), and ash (920.153). Carbohydrates were determined by difference. The energy value (Kcal) was calculated from the values for fat (9 Kcal g^{-1}), protein (4 Kcal g^{-1}), and carbohydrates (4 kcal g^{-1}) (European Union, 2011).

2.5.2. Texture profile analysis (TPA)

Instrumental TPA was carried out on raw samples using a TAXT Express texture analyzer (Stable Micro Systems Ltd., Surrey, England). For TPA, consisting of two compression cycles with a delay of 5 s between cycles and a crosshead speed of 2 mm/s, five samples per sample were compressed using an SMS P/0-5 probe and a 5 kg power cell, with the following settings: Pre-test speed of 2.0 mm/s, test speed of 2.0 mm/s, post- test speed of 2.0 mm/s and a trigger force of 5 g. The parameters, such as hardness (g) and chewiness (g), were estimated.

2.5.3. pH

The pH was determined using a pHmeter (model Mpa-210; Tecnopon, São Paulo, Brazil) previously calibrated with standard buffers (pH = 4.00; pH = 7.00 at 25 ºC) on 10 g of Boston butt pork samples homogenized in 90 mL of distilled water. The analysis was performed in sextuplicate.

2.5.4. Lipid oxidation

Lipid oxidation of Boston butt pork samples was determined using the thiobarbituric acid reactive substances (TBARS) assay of Triki, Herrero, Rodríguez-Salas, Jiménez-Colmenero, and Ruiz-Capillas (2013) with slight modifications. In a stomacher (Logen 1901, Logen Scientific, São Paulo, Brazil), 5 g of each sample was homogenized in 35 mL of 7.5% trichloroacetic acid (Êxodo Científica, São Paulo, Brazil) for 30 s. Then, the mixture was filtered, and 5 mL was collected and mixed with 5 mL of 20 mM thiobarbituric acid (TBA) (Êxodo Científica, São Paulo, Brazil). The resulting solution was kept in the dark at 20 ± 1.5 °C for 20 h. The color formed in the solution was determined using a spectrophotometer (SP - 22, Biospectro, Curitiba, Brazil) at 532 nm. The calibration curve was plotted with 1,1,3,3-tetraethoxypropane and the results were expressed as mg malondialdehyde (MDA) kg^{-1} sample. Nine determinations were performed for each treatment.

2.5.5. Instrumental color

Colorimetric analyzes were determined in quintuplicate using a Chroma Meter CR -5 (Minolta Business Technologies Inc., Tokyo, Japan) with illuminant D-65, 10° standard observer, and 8 mm aperture. Boston butt pork samples were removed from the packaging and exposed to atmospheric air for 10 min before color measurement. The instrumental color CIELAB (lightness - $L*$, redness - $a*$, yellowness - $b*$) was measured on the surface of Boston butt pork samples. Chroma (C*), hue angle (h°) and total color difference (ΔE) parameters were also calculated.

2.6. Microbiological properties

A 10 g sample of each Boston butt pork was aseptically transferred to a stomacher bag and homogenized with 90 mL of sterile 0.1% peptone water (Kasvi, São José dos Pinhais, Brazil) in a stomacher (LS Logen 1901, Logen Scientific, São Paulo, Brazil) for 1 min. Serial dilutions were made with 0.1% sterile peptone water (9 mL). Plate count agar (PCA; BD Difco, Le Pont de Claix, France) was used to count mesophilic microorganisms (48 h at 35 °C) and psychrophilic microorganisms (7 days at 4 °C). Violet red bile agar (VRBA; Kasvi, São José dos Pinhais, Brazil) was used for enumeration of Enterobacteriaceae (24 h at 35 °C). Baird-Parker agar (BP; Kasvi, São José dos Pinhais, Brazil) was used for coagulase-positive staphylococci (48 h at 35 °C). Acidified potato dextrose agar (PD; Himedia, Mumbai, India) was used to count molds and yeasts (25 °C for 5 days). The presence or absence of Salmonella in 25 g of the sample was also analyzed, according to da Silva et al. (2018).

2.7. Sensory evaluation

Sensory analysis was performed at the beginning of the storage period after the microbiological determinations. Boston Butt pork samples were cooked as described in the 2.3, cut into 4 × 4 × 2.5 cm pieces, and served in disposable plastic containers labeled with 3-digit random numbers. Water and unsalted crackers were served between samples to cleanse the palate. Seventy-two regular (at least once a month) consumers (58% female, 42% male, aged 20 to 60 years) of pork evaluated the sensory parameters (appearance, flavor, color, texture, taste, and overall acceptability (OA)) were rated using a 7-cm structured line scale with the terms "I extremely dislike" and "I extremely like" at each extreme. Purchase intention test was conducted using a 3-cm structured line scale with the terms "I definitely would not buy" and "I definitely would buy" at each extreme. Each item was later converted to a numerical scale.

2.8. Statistical Analysis

All the experiment was repeated twice and the analyzes were done at least in triplicate. Analysis of variance (ANOVA) was performed using SPSS 25.0 (SPSS Inc., Chicago, IL, USA) to analyze the effects of different concentrations of yellow mombin as marinade liquid and storage on the physicochemical, technological, microbiological, and sensory properties of Boston butt pork. A completely randomized design included treatment groups (C0, C50, C75, and C100) and storage time (0, 7, 14, and 21 days) as fixed effects and two replicates as a random effect. Means were compared using Tukey's HSD test, and differences were considered significant when $P < 0.05$. The marination's effect on the technological, physicochemical, and sensory properties of Boston butt pork was statistically analyzed using Principal Component Analysis (PCA) performed with XLSTAT student 2022.3.2.1353.

3. Results and discussion

3.1. Marinade liquid uptake (MLU), water holding capacity (WHC), and cooking loss (CL)

MLU, WHC, and CL of Boston butt pork samples are shown in Table 1. The MLU varied from -2.46% (C0) to 6.41% (C75). The results showed that the C0 sample lost water due to dehydration during the 20 h at 4 ºC as this was a non-marinated sample. The MLU of the Boston butt pork samples was due to the diffusion mechanism and the amount of yellow mombin juice (Tkacz, Modzelewska-Kapituła, Petracci, & Zduńczyk, 2021). However, different amounts of yellow mombin juice could not affect the MLU (P>0.05). MLU may be affected by the dependence of the meat used, the type, and the duration of the marination process. Similar results were reported by Siroli et al. (2020) for pork loin marinated in a solution of beer, olive oil, and concentrated lemon juice (7.3%) and Augustyńska-Prejsnar et al. (2019) for chicken marinated with acid whey (6.50%). High MLU percentages benefit the industry as they increase the yield of marinated meat products.

Excessive water loss is considered unfavorable economically and in terms of sensory characteristics of pork meat (Sun-Waterhouse, Kang, Ma, & Waterhouse, 2021). WHC values ranged from 83.99% to 85.31% without differences between the marinated treatments and the control (P>0.05). Higher WHC values in meat (such as those obtained) may be beneficial because less juice is lost during cooking process, which positively affects juiciness (Augustyńska-Prejsnar et al., 2019). Similar values (74.57%–77.60%) were reported by Nour (2022) for pork loin marinated in NaCl solution, sour cherry or plum juice.

The CL values ranged from 28.75% to 30.21% (Table 1), and no significant differences were found between samples (*P*>0.05), indicating that the addition of yellow mombin juice as a marinade liquid did not affect Boston butt pork CL. Low CL values are desirable because of the better juiciness of the meat. Similarly, Gao et al. (2015) related CL determined between 14.31% and 28.90% for pork loins non-marinated and marinated with a solution of NaCl, sodium pyrophosphate, sodium tripolyphosphate, sodium hexametaphosphate, white pepper powder, and water.

3.2. Physicochemical properties

3.2.1. Proximate composition

The proximate composition of the Boston butt pork samples is shown in Table 1. Significant differences were found between the control and marinated samples for moisture, protein, and fat content (*P*<0.05). However, no significant differences existed between the marinated and control samples for ash and carbohydrate content (*P*>0.05). The marinated Boston butt pork samples had the highest percentage of moisture, which was related to the absorption of yellow mombin juice by the marinated treatments and the loss of moisture from the C0 sample during the marinating period. As a result, the non-marinated sample had a higher dry matter content and the highest percentage of protein and fat. The observed reduction in protein and fat content in the marinated samples (Table 1) may be related to the leaching of sarcoplasmic proteins in the marinade liquid, the reduction in dry matter, and the inverse relationship between fat and moisture content (Pooona et al., 2020). The moisture, protein, and ash results are consistent with those reported by Ali et al. (2021) for Boston butt pork, which was 71.33%, 19.39%, and 1.06%, respectively. The energy values of Boston butt pork samples ranged from 132.74–151.51 Kcal 100 g^{-1} (Table 1) and the marinated Boston butt pork samples had lower energy values than the control (*P*<0.05).

3.2.2. Texture profile

Texture is one of the most important quality characteristics of meat and meat products for consumers. Fig. 2 shows the hardness (A) and chewiness (B) parameters during storage of Boston butt pork marinated in yellow mombin juice. The addition of yellow mombin juice affected ($P<0.05$) hardness values during storage and ranged from 58.03 to 126.90 g on day 0 to 100.43 to 274.97 g on day 21. In general, as the concentration of yellow mombin juice increased, the values of hardness decreased. At the beginning of the storage period, the C0 sample had the highest ($P<0.05$) hardness value (126.90 g). Among the marinated treatments, C50 showed higher ($P<0.05$) values than C75 but did not differ from the C100 treatment. In addition, the hardness values of the marinated treatments increased at day 7 ($P<0.05$) and were higher than C0. At the end of the storage period (day 21), the C0 treatment showed higher ($P<0.05$) hardness values than the marinated treatments, but there were no significant differences between the marinated samples ($P>0.05$). In contrast, C0 had the highest hardness value throughout the storage period ($P<0.05$), probably due to the higher water loss.

The results of chewiness (Fig. 2B) during storage varied from 28.41 to 67.95 g on day 0 to 66.46 to 148.82 g on day 21. On day 0, C0 (67.95 g) and C50 (62.63 g) had the highest values, whereas C75 (28.41 g) had the lowest values ($P<0.05$). At day 7, C75 and C100 were the only samples that increased at the beginning of storage ($P<0.05$). There were also significant differences between C0 (47.97 g) and C100 (116.43 g) ($P<0.05$). At day 14, there were no significant differences between samples ($P<0.05$). However, C100 decreased compared with day 7 ($P<0.05$). At day 21, C0 and C50 had the highest values for chewiness ($P<0.05$), while there were no significant differences between the marinated samples ($P>0.05$). The results for chewiness were like those for hardness; as the concentration of yellow mombin juice increased, the chewiness values decreased. For the C0 sample, increased chewiness values at the end of storage ($P<0.05$), while the marinated samples showed no significant difference between day 0 and day 21 (P>0.05). The lower hardness and chewiness values of the marinated Boston butt pork samples compared to the control during storage could be due to the low pH of the yellow mombin juice, which reduces the hardness of the meat by weakening the electrostatic interactions between the myofibrillar protein chains and the connective tissue (Nour, 2022; Wenham & Locker, 1976). However, the low hardness and chewiness of marinated meat are beneficial because the meat is tender and juicier, which increases consumer acceptance. The high standard deviation values of texture parameters were probably related to the non-homogeneous surface of the Boston butt pork slices.

3.2.3. pH

The pH values of marinated Boston butt pork varied during refrigerated storage (P<0.05). On day 0, the pH values ranged from 5.21 to 6.69 and decreased between 4.39 and 5.82 at the end of storage (P<0.05) (Table 2). In addition, pH values decreased as the concentration of yellow mombin juice throughout the storage period was due to the low pH of yellow mombin juice (2.90). Marinated meat products' low pH values are desirable because they improve texture, color, and WHC (Kumar, Singh, Pandey, Tanwar, & Kumar, 2017). Studies related low pH values in marinated pork, lamb, rabbit, and poultry to the low pH of marinade liquids (Unal, Alagöz, Çelik, & Sarıçoban, 2022; Simitzis, Zikou, Progoulakis, Theodorou, & Politis, 2021).

3.2.4. Lipid oxidation

Lipid oxidation is one of the main causes of the deterioration of meat and meat products, negatively affecting their nutritional, functional, and sensory properties (Domínguez et al., 2019). The TBARS values of the marinated Boston butt pork samples during storage are shown in Table 2. The values ranged from 0.116 to 0.176 mg MDA kg^{-1} at day 0 and 0.212 to 0.282

mg MDA kg^{-1} at day 21. At the beginning of storage, the C0 treatment showed lower (P<0.05) TBARS values than the C75 treatment. However, no differences were observed between the C0, C50, and C100 treatments. As expected, TBARS values increased during the storage period. Still, the C100 treatment had lower TBARS values on day 21 than at day 7 (P<0.05) (Table 2), which is probably related to the MDA decomposition into other compounds (Passos et al., 2022). In addition, the C50 sample presented highest values than the C0 and C100 (P<0.05), which may be related to a pro-oxidant effect of the ascorbic acid, phenols, and carotenes in the yellow mombin juice. However, the threshold for lipid oxidation above which off-flavor is perceived in the sensory analysis is higher than 1.0 mg MDA kg^{-1} (McKenna et al., 2005). Thus, the Boston butt pork marinated with yellow mombin juice in our study, which has valued no higher than 0.30 mg MDA kg^{-1} throughout the storage period, is well below this limit.

3.2.5. Instrumental color

Color is the first attribute that affects the consumer's acceptance of the meat. In this sense, the changes caused by the marination process and the stability during the storage period are important for pork meat. According to Table 2, using yellow mombin as a marinade liquid affected the color parameters during the storage of Boston butt pork. At the beginning of the storage period (day 0), $L*$ values ranged from 51.85 to 54.80, with the C100 sample having the highest value (P<0.05). This means that the Boston butt pork became lighter as yellow mombin was used at a concentration of 100%. The increase in lightness values was due to the acidity of the yellow mombin acidity, which promotes protein denaturation and changes in light reflectance and ionic strength (Nour, 2022; Unal et al., 2022). Other studies have already related an increase in $L*$ values of marinated meat in fruit juices (Sengun et al., 2019; Cho et al., 2021). During the storage period, a decrease (P<0.05) in the C0 lightness, while an increase (P<0.05) of this parameter in the marinated treatments were observed. At the end of the storage period, the C100 treatment showed the highest L^* value (57.22), while C0 had the lowest (49.92) (P<0.05).

At the beginning of storage, a^* values ranged from 3.86 to 7.03, with the C100 sample showing lower values than the others (P<0.05). Except for the C100 sample, all other marinated and non-marinated treatments showed a decrease in the a^* parameter throughout the storage period. All treatments showed a decrease (P<0.05) in redness throughout the storage, which is caused by the deterioration of myoglobin pigment, and the values were between 4.38 and 6.58 at the day 21 (Table 2).

The b^* value represents the yellowness of the Boston butt pork samples, which was higher in C100 than in C0, C50, or C75 at the end of the storage period (P<0.05). The higher b^* values observed for the marinated Boston butt pork during the storage period could be due to the presence of colorants (β-carotene and lycopene) in the yellow mombin juice (Oladunjoye et al., 2021; Maldonado-Astudillo et al., 2014). The results for the L^*, a^*, and b^* parameters indicate that the Boston butt pork samples marinated in yellow mombin juice were lighter, yellower, and less red than the control samples.

The h° and C* values are related to the visual discoloration of meat, as a large h° value is associated with lower color stability. In contrast, lower C^* values are associated with lower color intensity (King et al., 2011). At the beginning of the storage period, C100 treatment showed low C^* and high h° values (P<0.05). As a result of marinating with yellow mombin juice, the color of Boston butt pork changed from pale pink to orange pink. At day 0, the ΔE values ranged from 1.59 to 4.42, while they were between 5.31 and 7.53 at the end of the storage period (Table 2). According to Mokrzycki and Tatol (2011), when ΔE is higher than 5, two different colors can be noticed by an observer. In this context, different color can be perceived for C100 treatment during the whole storage period, while for treatments C50 and C75 this difference was perceived on the day 14.

3.3 Microbiology properties

Mesophilic, psychrophilic, Enterobacteriaceae, and mold and yeast count during storage of Boston butt pork samples marinated in yellow mombin juice are shown in Table 3. In general, marination with yellow mombin juice reduced the bacterial counts of the Boston butt pork samples. The higher concentration of yellow mombin, the lower the mesophilic count throughout the storage period. At the beginning of the storage period (day 0), mesophilic counts were higher in treatments C0 and C50 (5.08 and 4.99 log CFU g^{-1}, respectively) (P<0.05). In addition, the lower pH in samples C75 and C100 appears to have resulted in low mesophilic counts in these treatments. On days 7 and 14, mesophilic bacteria were intended to increase, but the marinated samples had lower counts than the control sample (P<0.05). At the end of the storage period, counts were from 5.69 to 8.63 log CFU g^{-1}, being the C100 sample having the lowest and the C0 sample with the highest count (P<0.05). Similar results were reported by Siroli et al. (2020) and Arcanjo et al. (2019) with pork loin marinated in beer, olive oil, concentrated lemon juice, and essential oils (oregano, rosemary, and juniper), and in beef marinated in wine, respectively. According to Brazilian law, marinated meat should not exceed mesophilic counts of 6 log CFU g^{-1} (Brasil, 2022). In this context, the microbiological shelf life of marinated Boston butt pork samples was extended to 21 days for C100 and to 14 days for C50 and C75 samples when stored at 4 ºC. As expected, the psychrophilic bacteria count increased throughout the storage period (P<0.05) (Table 3). At the beginning of the storage period, psychrophilic bacteria ranged from 3.22 to 4.41 log CFU g^{-1}. However, the count exceeded 7 log CFU g^{-1} after 21 days of storage for all treatments, but, C100 sample had the lowest values (P<0.05). Lower mesophilic and psychrophilic counts in marinated Boston butt pork samples are likely due to organic acids with antimicrobial properties in yellow mombin juice (Tiburski et al., 2011).

For Enterobacteriaceae, bacterial counts were lower at the beginning of storage (2.61 and 3.59 log CFU g^{-1}) but increased from day 7 onwards. On day 0, the C0 sample had lower Enterobacteriaceae counts than C50 and C75 ($P>0.05$). However, even with high Enterobacteriaceae counts at the end of the storage period, the marinated treatments had lower counts than the control ($P<0.05$) (Table 3). These results demonstrate the beneficial effect of the low pH of yellow mombin juice associated with its antimicrobial properties in slowing down the growth of spoilage bacteria (mesophilic, psychrotrophic, and Enterobacteriaceae) in the Boston butt pork samples. Concerning mold and yeast, the counts also increased during the storage period ($P<0.05$), but marinated treatments tended to have highest counts than control samples. Other studies have also found higher levels of molds and yeasts in marinated chicken and beef, which is related to their good ability to grow in acidic environments (Karam, Roustom, Abiad, El-Obeid, & Savvaidis, 2019; Lytou, Tzortzinis, Skandamis, Nychas, & Panagou, 2019). Coagulase-positive staphylococci and Salmonella were not detected, indicating good hygiene and sanitary conditions during processing and storage of Boston butt pork samples.

3.4. Sensory properties

The results of sensory attributes evaluated on the first day of storage of Boston butt pork samples marinated in yellow mombin juice are shown in Fig. 3A. In general, all attributes were affected by marination with yellow mombin juice. Compared to the control (C0), the marinated-treatments samples scored poorly for appearance, flavor, color, texture, taste, and OA ($P<0.05$). The poor scores for appearance and color of C50 (4.40), C75 (4.54), and C100 (3.84) may be due to their lightness (Table 2). In addition, the lower sensory attribute scores could be related to consumer expectations of pork meat and the higher frequency of consumption of non-marinated compared to marinated-meat. Among the marinated-treatments, C100 received the lowest score for appearance (3.84), flavor (3.95), color (4.05), and OA (3.23) (P<0.05). There were no significant differences (P>0.05) between the marinated treatments for texture and taste, with scores ranging from 4.27 to 4.68 and 3.22 to 3.88, respectively. For purchase intention, scores ranged from 1.30 to 2.34 (Figure 3B), and Boston butt pork samples marinated with the highest concentration of yellow mombin juice had the lowest score (P<0.05).

3.5. Principal component analysis

Figure 4 is a graphical representation of the degree of correlation between the Boston butt pork samples and the physicochemical, technological, and sensory results at day 0 of the storage period. This multivariate treatment of the Boston butt pork sample results allowed us to reduce the variables to two principal components that explained 91.33% of the total variability. The first component (PC1) explained 70.68% and the second (PC2) 20.65%. The figure shows that C0 (control) was most closely associated with physicochemical properties (a^*, pH, hardness, chewiness) and sensory attributes (color, appearance, flavor, taste, texture, and OA). This is consistent with the results in Table 2 and Figure 2, where C0 had the highest values for pH, a^*, hardness, and chewiness and received the highest score from panelists for all sensory attributes evaluated. Of the marinated treatments, C50 came closest to C0 in Figure 4. The physicochemical, technological, and sensory results confirm this.

As for C100, it was strongly correlated with L^*, h° and ΔE. These correlations are related to the results shown in Table 2. C75 was associated with b^*, C*, WHC, MLU, and TBARS. At the same time, C50 was correlated with CL. In the marinated treatments, C50 and C75 showed the highest correlation. In addition, sensory attributes, a^*, pH, hardness, and chewiness (related to C0) showed a negative correlation with L^*, h°, and ΔE (related to C100). This indicates the influence of yellow mombin juice as marinade liquid on these parameters. A similar case was found between CL and WHC. There is evidence that the higher the WHC, the lower the CL.

4. Conclusion

Marination with yellow mombin juice had no effect on MLU, WHC, and CL. On the other hand, 75% and 100% concentrations of yellow mombin juice improved pH, L^*, b^*, hardness and chewiness. At the same time, 50% and 75% concentrations of yellow mombin juice accelerated lipid oxidation in the Boston butt pork samples at the end of storage. The use of yellow mombin juice extended shelf life by up to 14 days at the 50% and 75% concentrations and by up to 21 days at the 100% concentration. Samples C50 and C75 were sensory and closest to the control sample. According to the results of technological, physicochemical, microbiological, and sensory properties, the use of 75% (C75) yellow mombin juice could be a viable alternative for marinated pork.

Declaration of Competing Interest

The author declares that there is no conflict of interest that could be perceived as prejudicing the impartiality of the research reported.

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References

Ali, M., Baek, K. H., Lee, Y., Kim, H. C., Park, Y., Jo, C., Jung, J. H., Park, H. C., & Nam, C. (2021). Comparative Meat Qualities of Boston Butt Muscles (*M. subscapularis*) from

Different Pig Breeds Available in Korean Market. *Food Science of Animal Resources, 41*(1), 71-84. https://doi.org/10.5851/kosfa.2020.e79

AOAC. (2005). *Official methods of analysis* (18th ed.). Association of Official Analytical Chemistry.

Arcanjo, N. M. O., Morcuende, D., Andrade, M. J., Padilla, P., Madruga, M. S., & Estévez, M. (2019). Bioactivities of wine components on marinated beef during aging. *Journal of Functional Foods, 57*, 19-30. https://doi.org/10.1016/j.jff.2019.03.040

Augustyńska-Prejsnar, A., Ormian, M., Hanus, P., Kluz, M., Sokołowicz, Z., & Rudy, M. (2019). Effects of marinating breast muscles of slaughter pheasants with acid whey, buttermilk, and lemon juice on quality parameters and product safety. *Journal of Food Quality*, *2019*. https://doi.org/10.1155/2019/5313496

Brasil - Agência Nacional de Vigilância Sanitária. (2019). Instrução Normativa n. 60, de 23 de dezembro de 2019. *Diário Oficial da União*. Retrieved from: https://www.gov.br/agricultura/pt-br/assuntos/inspecao/produtos-vegetal/legislacao-1/biblioteca-de-normas-vinhos-e-bebidas/instrucao-normativa-ndeg-60-de-23-de-dezembro-de-2019.pdf/view. Accessed October 25, 2022

Cho, J., Kim, H. J., Kwon, J. S., Kim, H. J., & Jang, A. (2021). Effect of marination with black currant juice on the formation of biogenic amines in pork belly during refrigerated storage. *Food Science of Animal Resources, 41*(5), 763. 763–778. https://doi.org/10.5851/kosfa.2021.e34

da Silva, N., Taniwaki, M. H., Junqueira, V. C., Silveira, N., Okazaki, M. M., & Gomes, R. A. R. (2018). Microbiological examination methods of food and water: a laboratory manual. CRC Press.

de Souza, V. R., Aniceto, A., Abreu, J. P., Montenegro, J., Boquimpani, B., de Jesuz, V. A., Campos, M. B., Marcellini, P. S., Silva, O. F., Cadena, R., & Teodoro, A. J. (2020).

Fruit-based drink sensory, physicochemical, and antioxidant properties in the Amazon region: Murici (*Byrsonima crassifolia* (L.) *Kunth* and *verbascifolia* (L.) DC) and tapereba (*Spondia mombin*). *Food Science & Nutrition*, *8*(5), 2341-2347. https://doi.org/10.1002/fsn3.1520

Domínguez, R., Pateiro, M., Gagaoua, M., Barba, F. J., Zhang, W., & Lorenzo, J. M. (2019). A comprehensive review on lipid oxidation in meat and meat products. *Antioxidants*, *8*(10), 429. https://doi.org/10.3390/antiox8100429

European Union. (2011). Regulation (EU) no. 1169/2011 of the European parliament and of the council on the provision of food information to consumers. *Official Journal of the European Union, 304*, 18 – 63.

Fadıloğlu. E. E., & Serdaroğlu. M. (2018). Effects of pre and post-rigor marinade injection on some quality parameters of Longissimus dorsi muscles. *Korean Journal for Food Science of Animal Resources, 38(2)*, 325. https://doi.org/10.5851/kosfa.2018.38.2.325

Gao, T., Li, J., Zhang, L., Jiang, Y., Liu, Y., Zhang, X., Gao, f., & Zhou, G. (2015). Effect of different tumbling marination methods and time on the quality characteristics of prepared pork chops. *Food Science and Technology, 35(3)*, 445-451. https://doi.org/10.1590/1678-457X.6710

Gómez, I., Janardhanan, R., Ibañez, F. C., & Beriain, M. J. (2020). The Effects of processing and preservation technologies on meat quality: sensory and nutritional aspects. *Foods*, *9*(10), 1416. https://doi.org/10.3390/foods9101416.

Hamm. R. (1961). Biochemistry of meat hydration. *Advances in Food Research, 10*, 355–463. https://doi.org/10.1016/S0065-2628(08)60141-X

Kaewthong, P., Wattanachant, C., & Wattanachant, S. (2021). Improving the quality of barbecued culled-dairy-goat meat by marination with plant juices and sodium bicarbonate. *Journal of Food Science and Technology, 58*(1), 333-342. https://doi.org/10.1007/s13197-020-04546-8

Karam, L., Roustom, R., Abiad, M. G., El-Obeid, T., & Savvaidis, I. N. (2019). Combined effects of thymol, carvacrol and packaging on the shelf-life of marinated chicken. *International Journal of Food Microbiology, 291*, 42-47. https://doi.org/10.1016/j.ijfoodmicro.2018.11.008

Kim, Y. J., Jin, S. K., Park, W. Y., Kim, B. W., Joo, S. T., & Yang, H. S. (2010). The effect of garlic or onion marinade on the lipid oxidation and meat quality of pork during cold storage. *Journal of Food Quality*, *33*, 171-185. https://doi.org/10.1111/j.1745-4557.2010.00333.x

Kumar, Y., Singh, P., Pandey, A., Tanwar, V. K., & Kumar, R. R. (2017). Augmentation of meat quality attributes of spent hen breast muscle (*Pectoralis major*) by marination with lemon juice vis-a-vis ginger extract. *Journal of Animal Research*, *7*(3), 523-529. https://doi.org/10.5958/2277-940X.2017.00077.8

Li, Y. X., Cabling, M. M., Kang, H. S., Kim, T. S., Yeom, S. C., Sohn, Y. G., Kim, S. H., Nam, K. C., & Seo, K. S. (2013). Comparison and correlation analysis of different swine breeds meat quality. *Asian-Australasian Journal of Animal Sciences*, *26*(7), 905. https://doi.org/10.5713/ajas.2012.12622

Linares, M. B., Garrido, M. D., Martins, C., & Patarata, L. (2013). Efficacies of garlic and *L. sakei* in wine-based marinades for controlling *Listeria monocytogenes* and *Salmonella* spp. in *chouriço de vinho*, a dry sausage made from wine-marinated pork. *Journal of Food Science*, *78*(5), M719-M724. https://doi.org/10.1111/1750-3841.12094

Lytou, A. E., Tzortzinis, K., Skandamis, P. N., Nychas, G. J. E., & Panagou, E. Z. (2019). Investigating the influence of organic acid marinades, storage temperature and time on the survival/inactivation interface of *Salmonella* on chicken breast fillets. *International*

Journal of Food Microbiology, *299*, 47-57. https://doi.org/10.1016/j.ijfoodmicro.2019.03.019

Maldonado-Astudillo, Y. I., Alia-Tejacal, I., Núñez-Colín, C. A., Jiménez-Hernández, J., Pelayo-Zaldívar, C., López-Martínez, V., Andrade-Rodríguez, M., Bautista-Baños, S., & Valle-Guadarrama, S. (2014). Postharvest physiology and technology of *Spondias purpurea L*. and *S. mombin L*. *Scientia Horticulturae*, *174*, 193-206. https://doi.org/10.1016/j.scienta.2014.05.016

Mattietto, R. D. A., Lopes, A. S., & Menezes, H. C. D. (2007). Stability of mixed cajá and umbu nectar. *Food Science and Technology, 27(3)*, 456-463. https://doi.org/10.1590/S0101-20612007000300006

McKenna, D. R., Mies, P. D., Baird, B. E., Pfeiffer, K. D., Ellebracht, J. W., & Savell, J. W. (2005). Biochemical and physical factors affecting discolorations characteristics of 19 bovine muscles. *Meat Science, 70,* 665-682. https://doi.org/10.1016/j.meatsci.2005.02.016

Mokrzycki, W., & Tatol, M. (2011). Color difference Delta E-A survey. *Machine Graphics & Vision International Journal, 20(*4), 383-411.

Mozuriene, E., Bartkiene, E., Krungleviciute, V., Zadeike, D., Juodeikiene, G., Damasius, J., & Baltusnikiene, A. (2016). Effect of natural marinade based on lactic acid bacteria on pork meat quality parameters and biogenic amine contents. *LWT - Food Science and Technology*, *69*, 319-326. https://doi.org/10.1016/j.lwt.2016.01.061

Nour, V. (2022). Effect of sour cherry or plum juice marinades on quality characteristics and oxidative stability of pork loin. *Foods*, *11*(8), 1088. https://doi.org/10.3390/foods11081088

OECD (Organization for Economic Co-operation and Development). Meat consumption, 2022 (indicator). Retrieved from: https://data.oecd.org/agroutput/meat-consumption.htm. Accessed, January 15, 2023.

Oladunjoye, A. O., Adeboyejo, F. O., Okekunbi, T. A., & Aderibigbe, O. R. (2021). Effect of thermosonication on quality attributes of hog plum (*Spondias mombin L.)* juice. *Ultrasonics Sonochemistry, 70,* 105316. https://doi.org/10.1016/j.ultsonch.2020.105316

Passos, R. S. F. T., Barreto, B. G., Leite, J. S. A. F., Trevisan, A. B., de Souza, C. O., da Silva, M. C. A., & Cavalheiro, C. P. (2022). Green tea extract as natural preservative in chicken patties: Effects on physicochemical, microbiological, and sensory properties. *Journal of Food Processing and Preservation*, *46*(2), e16224. https://doi.org/10.1111/jfpp.16224

Pooona, J., Singh, P., & Prabhakaran, P. (2020). Effect of kiwifruit juice and tumbling on tenderness and lipid oxidation in chicken nuggets. *Nutrition & Food Science, 50*(1), 74-83. https://doi.org/10.1108/nfs-12-2018-0352

Rupasinghe, R. A., Alahakoon, A. U., Alakolanga, A. W., Jayasena, D. D., & Jo. C. (2022). Oxidative stability of vacuum-packed chicken wings marinated with fruit juices during frozen storage. *Food Science of Animal Resources*. *42*(1). 61-72. https://doi.org/10.5851/kosfa.2021.e62

Sengun, I. Y., Goztepe, E., & Ozturk, B. (2019). Efficiency of marination liquids prepared with koruk (*Vitis vinifera L.*) on safety and some quality attributes of poultry meat. *LWT - Food Science and Technology, 113,* 108317. https://doi.org/10.1016/j.lwt.2019.108317

Simitzis, P., Zikou, F., Progoulakis, D., Theodorou, G., & Politis, I. (2021). A Note on the Effects of Yoghurt Acid Whey Marination on the Tenderness and Oxidative Stability of Different Meat Types. *Foods*, *10*(11), 2557. https://doi.org/10.3390/foods10112557

Singh, P., Yadav, S., Pathera, A., & Sharma, D. (2020). Effect of vacuum tumbling and red beetroot juice incorporation on quality characteristics of marinated chicken breast and leg meats. *Nutrition & Food Science, 50(1)*, 143-156. https://doi.org/10.1108/NFS-03-2019-0079

Siroli, L., Baldi, G., Soglia, F., Bukvicki, D., Patrignani, F., Petracci, M., & Lanciotti, R. (2020). Use of essential oils to increase the safety and the quality of marinated pork loin. *Foods*, *9*(8), 987. https://doi.org/10.3390/foods9080987

Stafussa, A. P., Maciel, G. M., Rampazzo, V., Bona, E., Makara, C. N., Junior, B. D., & Haminiuk, C. W. I. (2018). Bioactive compounds of 44 traditional and exotic Brazilian fruit pulps: phenolic compounds and antioxidant activity. *International Journal of Food Properties*, *21*(1), 106-118. https://doi.org/10.1080/10942912.2017.1409761

Sun-Waterhouse, D., Kang, W., Ma, C., & Waterhouse, G. I. (2021). Towards human well-being through proper chewing and safe swallowing: multidisciplinary empowerment of food design. *Journal of Future Foods*, *1*(1), 1-24. https://doi.org/10.1016/j.jfutfo.2021.09.001

Tiburski, J. H., Rosenthal, A., Deliza, R., Godoy, R. L., & Pacheco, S. (2011). Nutritional properties of yellow mombin (*Spondias mombin L.*) pulp. *Food Research International*, *44*(7), 2326-2331. https://doi.org/10.1016/j.foodres.2011.03.037

Tkacz, K., Modzelewska-Kapituła, M., Petracci, M., & Zduńczyk, W. (2021). Improving the quality of sous-vide beef from Holstein-Friesian bulls by different marinades. *Meat Science, 182*, 108639. https://doi.org/10.1016/j.meatsci.2021.108639

Triki, M., Herrero, A. M., Rodríguez-Salas, L., Jiménez-Colmenero, F., & Ruiz-Capillas, C. (2013). Chilled storage characteristics of low-fat. n-3 PUFA-enriched dry fermented sausage reformulated with a healthy oil combination stabilized in a konjac matrix. *Food Control*, *31*(1). 158-165. https://doi.org/10.1016/j.foodcont.2012.10.008

Unal, K., Alagöz, E., Çelik, İ., & Sarıçoban, C. (2022). Marination with citric acid, lemon, and grapefruit affects the sensory, textural, and microstructure characteristics of poultry meat. *British Poultry Science*, *63*(1), 31-38. https://doi.org/10.1080/00071668.2021.1963674

Wenham, L. M., & Locker, R. H. (1976). The effect of marinading on beef. *Journal of the Science of Food and Agriculture*, *27*(12), 1079-1084. https://doi.org/10.1002/jsfa.2740271202

Yusop, S. M., O'Sullivan, M. G., Kerry, J. F., & Kerry, J. P. (2010). Effect of marinating time and low pH on marinade performance and sensory acceptability of poultry meat. *Meat Science, 85*(4). 657-663. https://doi.org/10.1016/j.meatsci.2010.03.020

FIGURE CAPTIONS

Fig. 1 – Schematic diagram showing the preparation of marinated Boston butt pork samples and all the analyzes.

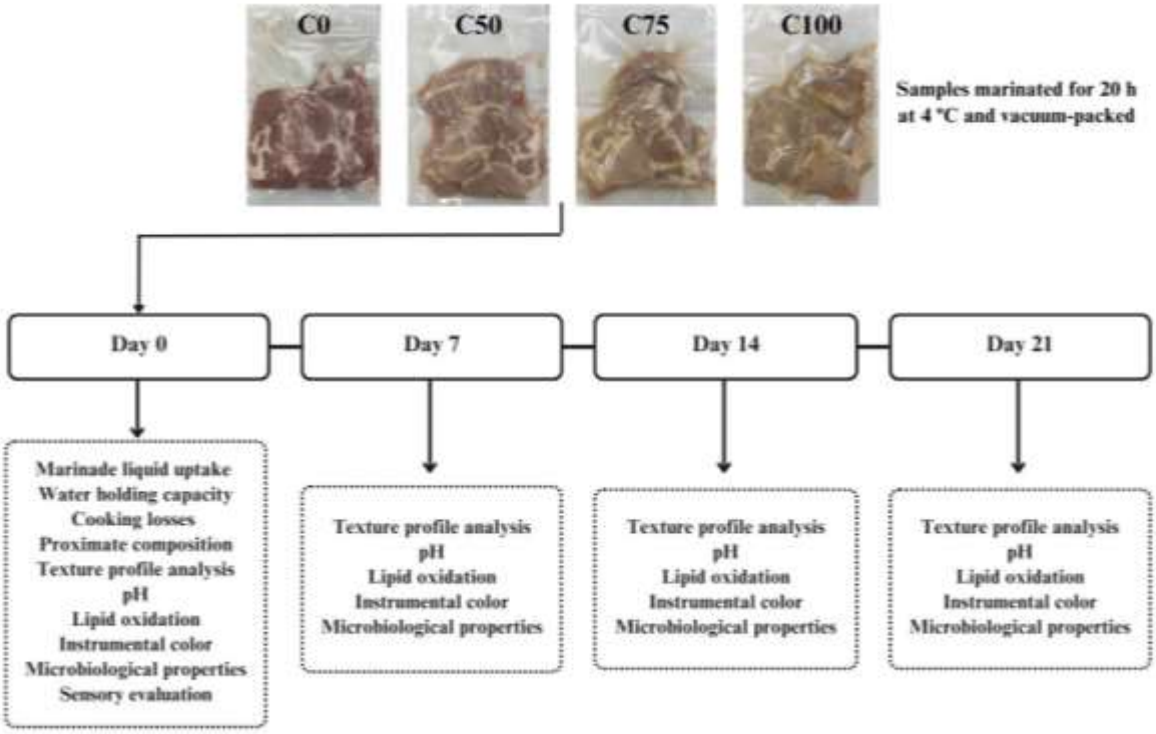
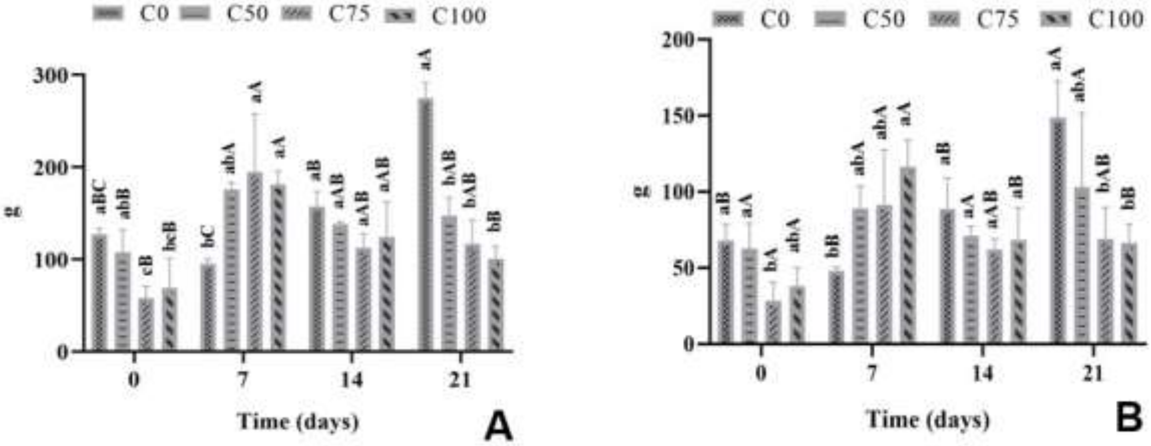
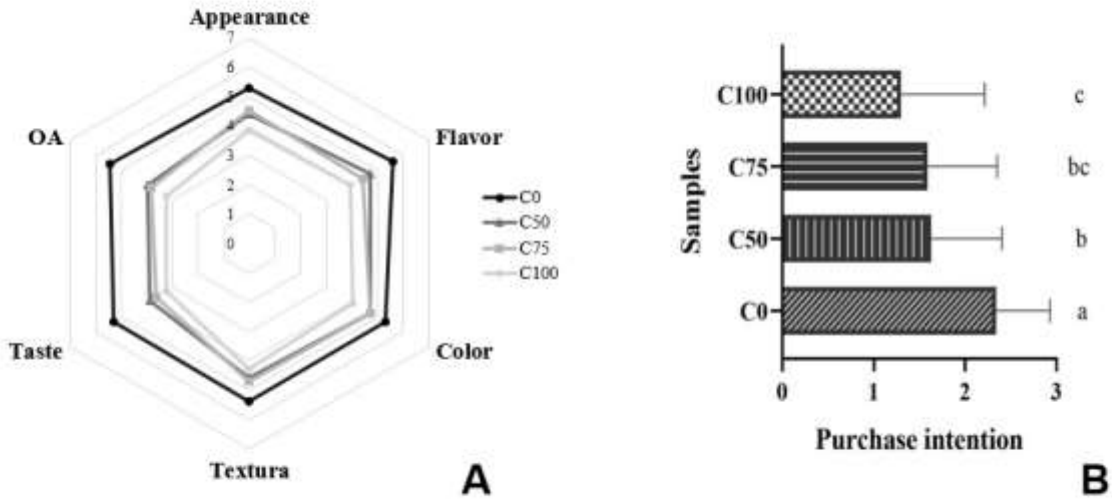


Fig. 2 – Hardness (A) and Chewiness (B) properties during refrigerated storage of Boston butt pork marinated with different concentrations of yellow mombin juice.



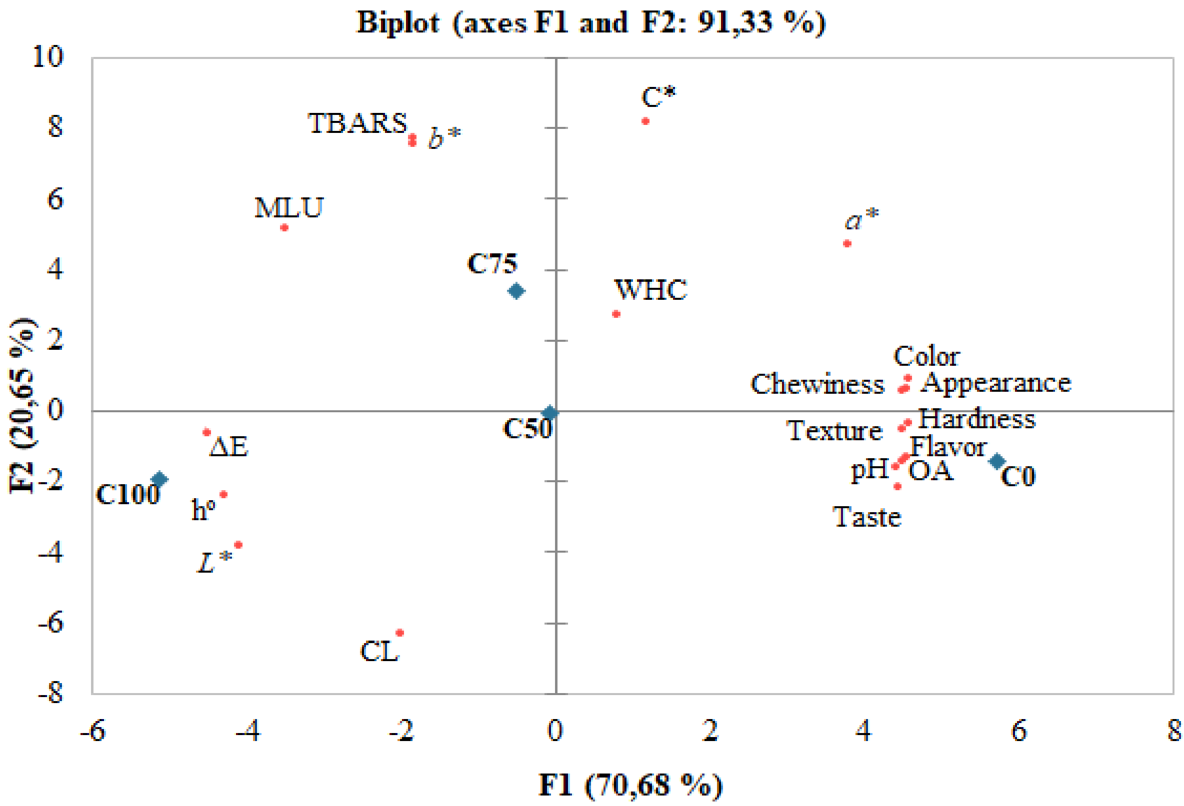
Different lowercase superscripts (a–d) indicate significant differences among treatments (*P*<0.05). Different uppercase superscripts (A–D) indicate significant differences among storage time (*P*<0.05). C0: non-marinated sample; C50: 50% yellow mombin juice; C75: 75% yellow mombin juice; C100: 100% yellow mombin juice.

Fig. 3 – Sensory scores (A) and purchase intention (B) of Boston butt pork marinated with yellow mombin juice in different concentrations.



Different lowercase superscripts (a–d) indicate significant differences among treatments (P<0.05). OA: Overall acceptability; C0: non-marinated sample; C50: 50% yellow mombin juice; C75: 75% yellow mombin juice; C100: 100% yellow mombin juice.

Fig. 4 – Principal component analysis (PCA) of technological, physicochemical, and sensory properties of Boston butt pork marinated with yellow mombin juice in different concentrations.



CL: Cooking loss; WHC: Water holding capacity; MLU: Marinade liquid uptake; OA: Overall acceptability. C0: non-marinated sample; C50: 50% yellow mombin juice; C75: 75% yellow mombin juice; C100: 100% yellow mombin juice.

Table 1 − Technological properties (%) and proximate composition (%) of Boston butt pork marinated with different concentrations yellow mombin juice.

	Treatments			
	C0	C50	C75	C100
MLU	-2.46 ± 0.64^{b}	4.44 ± 0.82^{a}	6.41 ± 1.73^{a}	4.21 ± 0.15^{a}
WHC	84.70 ± 0.20^{ab}	81.74 ± 1.38^{b}	85.31 ± 1.76^{a}	83.98 ± 1.30^{ab}
CL	29.36 ± 0.38^{a}	28.77 ± 2.52^{a}	28.75 ± 0.57^{a}	30.21 ± 1.39^{a}
Moisture	69.65 ± 0.92^{b}	73.78 ± 0.24^{a}	73.72 ± 0.29^{a}	73.37 ± 0.50^{a}
Protein	15.83 ± 0.17^{a}	12.89 ± 0.20^{b}	13.04 ± 0.03^{b}	13.07 ± 0.51^{b}
Fat	8.83 ± 0.03^{a}	8.16 ± 0.10^{b}	8.23 ± 0.21^{b}	8.24 ± 0.17^{b}
Ash	1.33 ± 0.23^{a}	1.30 ± 0.07^{a}	1.17 ± 0.06^{a}	1.11 ± 0.05^{a}
Carbohydrates	4.36 ± 1.91^{a}	3.87 ± 0.86^{a}	3.84 ± 0.83^{a}	4.20 ± 1.74^{a}
Energy value (Kcal 100 g^{-1})	151.51^{a}	132.74^{b}	133.91^{b}	134.86^{b}

Means ± standard error. Different lowercase superscripts (a–d) indicate significant differences among treatments (P<0.05). WHC: Water holding capacity; MLU: Marinade liquid uptake; CL: Cooking loss; C0: non-marinated sample; C50: 50% yellow mombin juice; C75: 75% yellow mombin juice; C100: 100% yellow mombin juice.

Table 2 – pH, lipid oxidation (mg MDA kg^{-1}), and instrumental color parameters of Boston butt pork marinated with yellow mombin juice in different concentrations during storage time.

		Storage time (days)			
		0	7	14	21
pH	C0	6.69 ± 0.03^{aA}	6.56 ± 0.07^{aB}	6.02 ± 0.08^{aC}	5.82 ± 0.01^{aD}
	C50	6.10 ± 0.03^{bA}	5.85 ± 0.02^{bB}	5.11 ± 0.05^{bC}	4.65 ± 0.01^{bD}
	C75	5.59 ± 0.03^{cA}	5.33 ± 0.03^{cB}	4.69 ± 0.02^{cC}	4.56 ± 0.01^{cD}
	C100	5.21 ± 0.02^{dA}	5.10 ± 0.03^{dB}	4.44 ± 0.02^{dC}	4.39 ± 0.01^{dD}
TBARS	C0	0.116 ± 0.009^{bB}	0.186 ± 0.007^{bAB}	0.208 ± 0.038^{aA}	0.212 ± 0.047^{bA}
	C50	0.136 ± 0.003^{abB}	0.293 ± 0.041^{aA}	0.265 ± 0.022^{aA}	0.282 ± 0.007^{aA}
	C75	0.176 ± 0.015^{aB}	0.265 ± 0.024^{abA}	0.259 ± 0.024^{aA}	0.260 ± 0.014^{abA}
	C100	0.143 ± 0.027^{abC}	0.288 ± 0.038^{aA}	0.264 ± 0.013^{aAB}	0.215 ± 0.007^{bB}
*L**	C0	51.85 ± 0.68^{bB}	54.17 ± 0.02^{aA}	49.50 ± 0.03^{cC}	49.92 ± 0.06^{dC}
	C50	53.03 ± 0.88^{bC}	53.83 ± 0.14^{bB}	53.77 ± 0.01^{cBC}	56.08 ± 0.10^{cA}
	C75	52.31 ± 0.99^{bC}	53.67 ± 0.08^{cB}	57.07 ± 0.01^{aA}	56.97 ± 0.02^{bA}
	C100	54.80 ± 0.12^{aC}	51.03 ± 0.02^{dD}	55.10 ± 0.01^{bB}	57.22 ± 0.03^{aA}
*a**	C0	7.03 ± 0.29^{aA}	6.65 ± 0.26^{aAB}	6.92 ± 0.33^{aAB}	6.58 ± 0.11^{aB}
	C50	6.30 ± 0.14^{bB}	6.49 ± 0.04^{abA}	6.14 ± 0.04^{bC}	4.38 ± 0.07^{bD}
	C75	6.97 ± 0.20^{aA}	6.36 ± 0.07^{bB}	4.22 ± 0.01^{dD}	4.48 ± 0.02^{bC}
	C100	3.86 ± 0.10^{cD}	6.69 ± 0.05^{aA}	5.75 ± 0.01^{cB}	4.23 ± 0.10^{cC}
*b**	C0	9.98 ± 0.20^{bA}	9.82 ± 0.20^{dA}	8.99 ± 0.11^{dC}	9.27 ± 0.06^{dB}
	C50	10.44 ± 0.48^{bC}	11.38 ± 0.07^{cB}	12.63 ± 0.03^{bA}	10.49 ± 0.07^{cC}
	C75	11.95 ± 0.66^{aA}	12.43 ± 0.16^{aA}	10.80 ± 0.02^{cB}	10.90 ± 0.11^{bB}
	C100	10.65 ± 0.10^{bD}	11.97 ± 0.15^{bB}	13.23 ± 0.02^{aA}	11.32 ± 0.12^{aC}
*C**	C0	12.20 ± 0.23^{bA}	11.85 ± 0.06^{dB}	11.35 ± 0.29^{bC}	11.37 ± 0.09^{cC}
	C50	12.20 ± 0.36^{bC}	13.10 ± 0.06^{cB}	14.20 ± 0.35^{aA}	11.37 ± 0.05^{cD}
	C75	13.84 ± 0.48^{aA}	13.96 ± 0.16^{aA}	11.60 ± 0.02^{bB}	11.79 ± 0.10^{bB}
	C100	11.33 ± 0.11^{cD}	13.72 ± 0.15^{bB}	14.42 ± 0.02^{aA}	12.08 ± 0.10^{aC}
h°	C0	54.83 ± 1.26^{cA}	55.83 ± 1.60^{cA}	52.44 ± 0.96^{dB}	54.63 ± 0.39^{cA}
	C50	58.83 ± 1.66^{bC}	60.31 ± 0.23^{bC}	64.08 ± 0.18^{cB}	67.36 ± 0.43^{bA}
	C75	59.69 ± 2.04^{bC}	62.79 ± 0.35^{aB}	68.65 ± 0.09^{aA}	67.67 ± 0.24^{bA}
	C100	70.10 ± 0.39^{aA}	60.80 ± 0.12^{bC}	66.51 ± 0.06^{bB}	69.51 ± 0.58^{aA}
ΔE	C0	-	-	-	-

C50	1.59 ± 0.72^{bC}	1.66 ± 0.23^{cC}	5.68 ± 0.06^{cB}	6.66 ± 0.10^{bA}
C75	2.25 ± 0.78^{bC}	2.69 ± 0.33^{bC}	8.25 ± 0.06^{aA}	7.53 ± 0.06^{aB}
C100	4.42 ± 0.38^{aC}	3.82 ± 0.05^{aD}	7.14 ± 0.03^{bA}	5.31 ± 0.14^{cB}

Means ± standard error. Different lowercase superscripts (a–d) indicate significant differences among treatments ($P<0.05$). Different uppercase superscripts (A–D) indicate significant differences among storage time ($P<0.05$). C0: non-marinated sample; C50: 50% yellow mombin juice; C75: 75% yellow mombin juice; C100: 100% yellow mombin juice.

Table 3 – Microbiological properties (log CFU g^{-1}) during storage time of Boston butt pork marinated with yellow mombin juice in different concentrations.

		Storage time (days)			
Microorganisms		0	7	14	21
Mesophilic	C0	5.08 ± 0.52^{aC}	5.78 ± 0.44^{aBC}	6.81 ± 0.41^{aB}	8.63 ± 0.44^{aA}
	C50	4.99 ± 0.29^{aBC}	4.74 ± 0.14^{bC}	5.58 ± 0.49^{bB}	6.81 ± 0.25^{bA}
	C75	3.98 ± 0.13^{bC}	4.93 ± 0.08^{bB}	5.34 ± 0.16^{bB}	6.68 ± 0.29^{bA}
	C100	3.62 ± 0.11^{bC}	4.47 ± 0.31^{bB}	4.84 ± 0.31^{bB}	5.69 ± 0.26^{cA}
Psychrophilic	C0	4.41 ± 0.28^{aC}	5.14 ± 0.12^{aB}	7.38 ± 0.14^{aA}	7.71 ± 0.03^{aA}
	C50	4.20 ± 0.32^{abC}	4.68 ± 0.25^{abB}	7.30 ± 0.06^{aA}	7.62 ± 0.11^{abA}
	C75	3.55 ± 0.47^{bcC}	4.48 ± 0.22^{bB}	7.22 ± 0.14^{aA}	7.50 ± 0.11^{bA}
	C100	3.22 ± 0.09^{cD}	4.44 ± 0.10^{bC}	6.53 ± 0.13^{bB}	7.10 ± 0.09^{cA}
Enterobacteriaceae	C0	2.61 ± 0.22^{cC}	5.30 ± 0.13^{aB}	5.61 ± 0.23^{aB}	6.15 ± 0.20^{aA}
	C50	3.59 ± 0.12^{aC}	4.32 ± 0.25^{bB}	5.43 ± 0.06^{abA}	5.70 ± 0.04^{bA}
	C75	3.02 ± 0.12^{bC}	4.24 ± 0.18^{bcB}	5.05 ± 0.32^{bcA}	5.54 ± 0.21^{bcA}
	C100	2.71 ± 0.08^{bcD}	3.77 ± 0.32^{cC}	4.61 ± 0.20^{cB}	5.30 ± 0.15^{cA}
Molds and yeasts	C0	1.23 ± 0.29^{bB}	2.09 ± 0.09^{cA}	2.35 ± 0.11^{cA}	2.49 ± 0.12^{cA}
	C50	2.38 ± 0.24^{aB}	3.68 ± 0.09^{bA}	3.50 ± 0.20^{bA}	3.62 ± 0.21^{bA}
	C75	1.90 ± 0.32^{aB}	3.85 ± 0.08^{abA}	3.91 ± 0.01^{abA}	4.10 ± 0.18^{aA}
	C100	1.69 ± 0.36^{abB}	4.05 ± 0.25^{aA}	4.06 ± 0.24^{aA}	4.25 ± 0.14^{aA}

Means ± standard error. Different lowercase superscripts (a–d) indicate significant differences among treatments ($P<0.05$). Different uppercase superscripts (A–D) indicate significant differences among storage time ($P<0.05$). C0: non-marinated sample; C50: 50% yellow mombin juice; C75: 75% yellow mombin juice; C100: 100% yellow mombin juice.