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VALORIZAÇÃO DA POLPA DE GUABIROBA (*CAMPOMANESIA XANTHOCARPA* O BERG) VISANDO O DESENVOLVIMENTO E A CARACTERIZAÇÃO DE PRODUTOS LÁCTEOS FUNCIONAIS.

Florianópolis
2025

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Orientador(a): Prof.(a), Dr.(a) Elane Schwinden Prudêncio.
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O presente trabalho em nível de mestrado foi avaliado e aprovado, em 17/02/2025, pela banca examinadora composta pelos seguintes membros:

Prof.(a), Dr.(a) Elane Schwinden Prudêncio - Presidente
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Dedico ao meu amado pai (*in memoriam),* o homem mais íntegro, bondoso, trabalhador, honesto e o maior pescador de tucunaré que já existiu.

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RESUMO

A pesquisa avaliou a adição de diferentes concentrações de polpa de guabiroba (*Campomanesia xanthocarpa* O. Berg) em Doce de leite (5, 10, 15, 20, 25 e 30%) e Queijo fresco (5, 10 e 15%). O uso da polpa foi pensado para maximizar estudos a partir de um fruto silvestre e o seu potencial mercadológico como um produto lácteo inovador com boas características nutricionais e funcionais. No doce de leite, analisou-se as propriedades físico-químicas, cor (a*), capacidade antioxidante, compostos fenólicos totais e carotenoides. Já para o queijo, foram avaliadas características físico-químicas, cor, textura, capacidade antioxidante, perfil multielementar e capacidade antimicrobiana. No doce de leite, a adição da polpa não alterou os níveis de proteína, mas 5% (polpa) apresentou aumento de 123% em relação ao mínimo estabelecido. Todas as formulações com polpa registraram redução do pH, umidade e sólidos solúveis totais ($p < 0,05$), além do aumento no parâmetro de cor a*, conferindo tonalidade alaranjada. A capacidade antioxidante, medida pelo DPPH, mostrou que as amostras com 15 a 30% não diferiram ($p > 0,05$), com valores entre 283,18 e 360,38 mg TEAC/100g. O teor de compostos fenólicos totais aumentou em 49,62% na formulação com 30% de polpa. A polpa aumentou a concentração de α-caroteno, β-caroteno, β-criptoxantina e λ-caroteno, sendo o β-caroteno o de maior concentração, até 6,67 vezes superior à amostra controle. No Queijo fresco, a adição de polpa resultou na diminuição da capacidade de água, cinzas, pH e acidez titulável. A coloração apresentou alteração visível e tendência ao amarelo-avermelhado. Houve redução da firmeza, elasticidade e gomosidade. O teor de compostos fenólicos totais aumentou entre 1,4 e 2,5 vezes nas formulações com 10 e 15% de polpa. A capacidade antioxidante *in vitro* cresceu de forma significativa ($p < 0,05$), com aumentos de 220, 238 e 268% (DPPH) e 13, 28 e 48% (ABTS). O teor de carotenoides aumentou em todas as formulações com polpa, destacando-se o β-caroteno. A lactose não foi afetada ($p > 0,05$), mas a formulação com 15% de polpa apresentou redução nos níveis de galactose, sem alteração significativa ($p > 0,05$) nos teores de glicose, sacarose e frutose. A adição da polpa elevou os níveis de compostos hidrofílicos e lipofílicos, identificando-se ácidos orgânicos, aminoácidos e açúcares ácidos. No perfil multielementar, os principais elementos encontrados foram Ca > P > S > K > Mg > Zn > Sr, sem a presença de elementos tóxicos. Quanto à capacidade antimicrobiana, as amostras com 5, 10 e 15% de polpa apresentaram redução de 98, 97 e 96% na contagem de *Staphylococcus aureus* e de 21, 0 e 33% para *Escherichia coli*, respectivamente. Os resultados indicam que a adição de polpa de guabiroba pode melhorar a qualidade nutricional e funcional dos produtos lácteos, além de oferecer propriedades antimicrobianas. O uso da polpa representa uma alternativa viável para a indústria de laticínios, promovendo a diversificação da produção e explorando matérias-primas pouco utilizadas. A inclusão desse fruto silvestre, rico em compostos bioativos, amplia o conhecimento sobre ingredientes funcionais e seus benefícios para a saúde.

Palavras-chave: Guabiroba (*Campomanesia xanthocarpa* O Berg); Compostos bioativos; Produtos lácteos funcionais.

ABSTRACT

The study evaluated the addition of different concentrations of guabiroba pulp (*Campomanesia xanthocarpa* O. Berg) in Dulce de leche (5, 10, 15, 20, 25, and 30%) and fresh cheese (5, 10, and 15%). The use of the pulp was intended to maximize studies on a wild fruit and its market potential as an innovative dairy product with good nutritional and functional characteristics. In Dulce de leche, the physicochemical properties, color (a*), antioxidant capacity, total phenolic compounds, and carotenoids were analyzed. For the cheese, physicochemical characteristics, color, texture, antioxidant capacity, multielemental profile, and antimicrobial capacity were evaluated. In Dulce de leche, the addition of the pulp did not alter protein levels, but the 5% (pulp) formulation showed a 123% increase compared to the minimum established. All pulp-added formulations recorded a reduction in pH, moisture, and total soluble solids ($p < 0.05$), along with an increase in the color parameter a*, giving an orange hue. The antioxidant capacity, measured by DPPH, showed that samples with 15 to 30% did not differ ($p > 0.05$), with values between 283.18 and 360.38 mg TEAC/100g. The total phenolic content increased by 49.62% in the 30% pulp formulation. The pulp increased the concentration of α-carotene, β-carotene, β-cryptoxanthin, and λ-carotene, with β-carotene being the most concentrated—up to 6.67 times higher than the control sample. In fresh cheese, the addition of pulp resulted in reduced water-holding capacity, ash content, pH, and titratable acidity. The color showed visible changes and a tendency toward a yellowish-reddish hue. There was a reduction in firmness, elasticity, and gumminess. The total phenolic content increased between 1.4 and 2.5 times in formulations with 10% and 15% pulp. The in vitro antioxidant capacity increased significantly ($p < 0.05$), with rises of 220%, 238%, and 268% (DPPH) and 13%, 28%, and 48% (ABTS). Carotenoid content increased in all pulp-added formulations, with β-carotene standing out. Lactose was not affected ($p > 0.05$), but the 15% pulp formulation showed reduced galactose levels, with no significant change ($p > 0.05$) in glucose, sucrose, and fructose content. The addition of pulp increased the levels of hydrophilic and lipophilic compounds, identifying organic acids, amino acids, and acidic sugars. In the multielemental profile, the main elements found were Ca > P > S > K > Mg > Zn > Sr, with no presence of toxic elements. Regarding antimicrobial capacity, samples with 5%, 10%, and 15% pulp showed reductions of 98%, 97%, and 96% in *Staphylococcus aureus* counts and 21%, 0%, and 33% for *Escherichia coli*, respectively. The results indicate that adding guabiroba pulp can improve the nutritional and functional quality of dairy products while also providing antimicrobial properties. The use of the pulp represents a viable alternative for the dairy industry, promoting production diversification and exploring underutilized raw materials. The inclusion of this wild fruit, rich in bioactive compounds, expands knowledge about functional ingredients and their consumption benefits.

Keywords: Guabiroba (*Campomanesia xanthocarpa* O BERG); Bioactive compounds; Functional dairy products.

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LISTA DE ABREVIATURAS E SIGLAS

AAS	Ácido Acetilsalicílico
ABRAFRURAS	Associação Brasileira de Produtores e Exportadores de Frutas e derivados
ABTS	A capacidade de inibição do radical $ABTS^{+}$ (2,2AZINOBIS(3-ethylbenzothiazoline6sulfonicacid)
ANOVA	Análise de variância
DNA	ácido desoxirribonucleico
DPPH	capacidade antioxidante por via radical livre DPPH (2,2 difenil-1-picril-hidrazil)
GAE	Equivalentes de ácido gálico
LAB	Lactobacilos
LDL	Lipoproteínas de baixa densidade
MEV	Microscopia eletrônica de varredura
ORAC	Capacidade de absorção do radical de oxigênio
TACO	Tabela Brasileira de Composição de alimentos
TEAC	Equivalente do Trolox
UV/Vis	Espectroscopia UV/visível

SUMÁRIO

INTRODUÇÃO

A produção de frutas silvestres no Brasil é um fator importante para o desenvolvimento econômico e social. Atualmente o país está entre os três maiores exportadores de frutas no mundo,E com mais de 45 milhões toneladas anualmente, permitindo a exportação e comercialização interna dos frutos (Barbieri *et al.*, 2018; Clerici e Carvalho-Silva, 2011). Grande parte da produção nacional, são variedades exóticas com alto potencial sensorial e nutricional, além de elevado índice de compostos bioativos, carotenoides, compostos fenólicos e ácidos graxos que desempenham papel fundamental para o avanço nas pesquisas para o uso desses frutos na alimentação (Dantas, 2018; Milanezzi, 2022). Dentre esses frutos, algumas espécies silvestres se destacam, como o caso da família *Myrtaceae.*

A família *Myrtaceae* pode ser considerada como uma das principais frutíferas do mundo, com 145 gêneros e 5970 espécies espalhadas pelo globo (“Myrtaceae — A Lista de Plantas”, 2013; Farias *et al.*, 2020). Esses autores relatam que o gênero *Campomanesia* é constituído por uma grande variedade de espécies com grande potencial para ser explorado economicamente, e apresentam elevado potencial nutricional e funcional, além de fontes de fitoquímicos como compostos fenólicos, carotenoides e compostos voláteis. Sabe-se que uma delas é a *Campomanesia Xanthocarpa* O Berg popularmente conhecida como guabiroba.

A guabiroba (*Campomanesia xanthocarpa* O BERG) segundo Silva *et al* (2009), é uma fruta com casca fina, verde quando jovem e amarelo-alaranjada quando madura, é uma baga glabra, com média de 6g, possuem 18% de epicarpo, 55% de mesocarpo, 10% de endocarpo, 13% de semente e 3,9% de cálice. Nativa do Brasil e distribuída nas regiões Sul, Sudeste e Centro-oeste, onde o bioma predominante é o Cerrado e a Mata Atlântica. A maior incidência é entre os estados de Minas Gerais, São Paulo até o extremo do Rio Grande do Sul (Alves., *et al.*, 2013; Teleginski *et al.*, 2018; Vallilo *et al.*, 2006). Esses autores relatam que seu florescimento ocorre de agosto a setembro e a frutificação de novembro a dezembro. Ocorre em altitudes < 2.000 m acima do mar, pode ser encontrada no Brasil, Peru, Equador, Colômbia e raramente possuem cultivos domésticos, tendo sua produção diretamente atrelado ao extrativismo e não há registro da comercialização do fruto (Barbieri *et al.*, 2017; Lima *et al.*, 2016; Sant’anna *et al.*, 2017).

Estudos indicam que o uso de frutas silvestres como a guabiroba tem despertado interesse em pesquisadores para o enriquecimento de produtos lácteos afim de evidenciar a alegação das propriedades funcionais desses alimentos. Prestes *et al*, (2021) relatam que extratos ricos em bioativos como a guabiroba, uma fruta silvestre tem apresentado resultados relevantes para o uso em produtos lácteos com alegação funcional devido às interações entre a matriz do alimento e os componentes do fruto.

Os produtos lácteos assim como doce de leite e queijo fresco apresentam alto consumo devido às suas características nutricionais e funcionais que está diretamente associado à boa saúde. Feil *et al.* (2020) relatam que os derivados do leite constituem um alimento globalmente essencial na alimentação humana por fornecer proteínas e minerais essenciais para o crescimento. Esses componentes têm despertado interesse na comunidade cientifica que buscam analisar a interação, biodisponibilidade e a bioatividade dos produtos lácteos adicionados de extratos para alegação de propriedade funcional. Segundo Bouarab *et al* (2019), os produtos funcionais são alimentos que contém compostos bioativos bioativos (polifenóis, carotenoides, vitaminas e/ou microrganismos) e esses aditivos necessariamente devem apresentar algum benefício para o consumidor.

Há na literatura estudos com o uso da polpa de guabiroba para melhorias em derivados lácteos. Prestes *et al.* (2021) identificaram que a polpa contribuiu para maior multiplicação e sobrevivência de *Bifidobacterium* BB-12, L. *bulgaricus* e *S. thermophilus* em uma simulação gastrointestinal. Os mesmos autores posteriormente identificaram que 10% de polpa de guabiroba aumenta em 1,6 vezes mais os compostos fenólicos, aumenta em 164% os carotenoides e potencial probiótico em bebida láctea processada com soro concentrado (Prestes *et al.*, 2023). Ainda assim, não há registros da comercialização de produtos lácteos adicionados de polpa de guabiroba ou a adição da polpa em produtos lácteos como o doce de leite ou queijo fresco.

A partir dessa perspectiva, esse estudo objetivou a valorização da polpa de guabiroba *(Campomanesia xanthocarpa O.* Berg*).* como fonte rica em compostos bioativos para melhorias do potencial tecnológico de produtos lácteos funcionais. Foi avaliada a adição de diferentes concentrações (5, 10, 15, 20, 25 e 30%) da polpa para melhorias da qualidade físico-química e funcional de Doce de leite. E ainda, o uso da polpa no desenvolvimento de um novo queijo fresco, o qual foi analisado as características nutricionais, físico-químicas, cor, textura, capacidade antioxidante, compostos hidrofílicos e lipofílicos, perfil mineral elementar e capacidade antimicrobiana da adição de três concentrações (5, 10 e 15%) no queijo.

(a) Capítulo 1 - **Revisão Bibliográfica** Constitui um embasamento bibliográfico abordando os principais temas envolvidos no trabalho: Frutas silvestres, *Campomanesia xanthocarpa* o. BERG (Guabiroba), composição e compostos bioativos, produtos lácteos funcionas, doce de leite e queijos frescos.

(b) Capítulo 2 – "**The potential of guabiroba (*Campomanesia xanthocarpa* O. Berg) pulp as a functional ingredient aiming to increase the nutritional dulce de leche Properties".** o objetivo do presente estudo foi adicionar a polpa de guabiroba (5, 10, 15,20, 25 e 30%) em doce de leite. Todos os doces de leite apresentaram as seguintes análises: proteína, pH, umidade, sólidos solúveis totais, parâmetro de cor a*, capacidade antioxidante, compostos fenólicos totais e teor de carotenoides.

(c) Capítulo 3 – "**The potential of guabiroba pulp application and its aiming at the elaboration of functional fresh cheeses".** Esse estudo objetivou a adição de diferentes concentrações (5, 10 e 15%) de polpa de guabiroba em queijos frescos. As formulações foram avaliadas quanto: Propriedades físico-químicas (Proteinas, umidade, acidez titulável, A_w, pH e cinzas), cor, textura, compostos fenólicos totais, capacidade antioxidante *in vitro,* açucares, carotenoides, compostos hidrofílicos e lipofílicos, perfil multielementar e atividade antimicrobiana.

CAPÍTULO 1

Revisão Bibliográfica

1 REVISÃO BIBLIOGRÁFICA

2 FRUTAS SILVESTRES BRASILEIRAS.

Com uma biodiversidade variada, o Brasil se destaca mundialmente pela quantidade de espécies frutíferas em seu território, a flora brasileira é considerada um berçário para espécies de plantas silvestres com alto potencial tecnológico e agroindustrial (Grutzmann Arcari *et al*., 2020; Neto, 2006). O Brasil segue na terceira posição do ranking mundial de produção de frutas, perdendo apenas para a China e Índia representando 5% da produção mundial com mais de 43 milhões de toneladas e 65% dessa produção destinada ao consumo interno e 36% à exportação (Pereira *et al*., 2012; ABRAFRUTAS, 2017).

A partir de iniciativas, o processamento de frutas silvestres tem apresentado elevado potencialidade não apenas devido ao potencial tecnológico, mas também para a diversificação da produção de novos produtos com alto valor funcional e nutricional para a saúde humana (Clerici; Carvalho-Silva, 2011). No entanto, paradoxalmente, o consumo e a produção desse tipo de fruto no Brasil apresentam deficiência que pode estar relacionada a falta de conhecimento dos meios de produção e preservação pós-colheita (Leterme *et al.*, 2006).

A ausência de informações sobre frutas silvestres interfere diretamente na não disseminação de informações das propriedades tecnológicas e funcionais desses alimentos, acarretando o não consumo de forma comercial, isso se deve à falta de pesquisas sobre a viabilidade e sua introdução no mercado (Clerici; Carvalho-silva, 2011; Taver *et al*., 2022).

É bem verdade que a região Amazônica e o Cerrado devido às condições climáticas e territoriais apresentam maior números de espécies frutíferas nativas no Brasil, no entanto, o Sul também se destaca pela riqueza em frutos silvestres com alto potencial tecnológico, dentre eles os da família botânica *Myrtaceae,* que apresenta maior número de espécies com características para o consumo humano (Pereira, et al., 2012). Em termos de área, o Cerrado brasileiro, bioma com maior incidência de frutos da família *Myrtaceae* é ultrapassado apenas pela Floresta Amazônica, representando 23% do território nacional e 2 milhões de km^2 do Brasil Central estendendo-se desde as margens da floresta amazônica até regiões periféricas de São Paulo e Paraná (BRASIL., 2011).

2.1 FAMÍLIA BOTÂNICA *MYRTACEAE*

Sendo composta por mais de 145 gêneros e 5970 espécies, a família *Myrtaceae* é conhecida pelo mundo, tem incidência em florestas tropicais e subtropicais da América do Sul, Sudeste Asiático e Austrália, no Brasil apresenta 23 gêneros e aproximadamente 1.000 espécies

(THE PLANT LIST - MYRTACEAE, 2013; SOUZA; LORENZI, 2005). São arvores ou arbustos aromáticos que frequentemente produzem frutos comestíveis, alguns frutos da família *Myrtaceae* são utilizados na medicina popular devido às propriedades fitoterápicas, antioxidantes, antirreumático, anti-inflamatório e para diminuir colesterol no sangue (Stefanello, 2011).

A incidência desse tipo de espécie arbórea pode ser notada em diversos países da América do Sul, como Paraguai, Uruguai, Argentina, Bolívia e Equador. No Brasil, está distribuída nos estados da Bahia, Distrito Federal, Goiás, Minas Gerais, São Paulo, Paraná, Santa Catarina e Rio Grande do Sul (Lima *et al.*, 2016).Os frutos da família *Myrtaceae* são conhecidos pelo alto teor de compostos bioativos e capacidade antioxidantes, além disso, algumas frutas podem ser consumidas *in natura* e apresentam elevado potencial para o desenvolvimentos de novos produtos funcionais, como iogurtes, licores, sorvetes, barras de cereais, doces e geleias (Pereira *et al*., 2012; Prestes *et al*., 2021;Stefanello; Pascoal; Salvador, 2011).

No geral, frutos da família *Myrtaceae* são do tipo baga, apresentam alto rendimento de polpa, características sensoriais desejáveis, boas quantidades de fitoquímicos, ácidos orgânicos, açucares, vitaminas, polissacarídeos, sacarídeos, propriedade antioxidante, polifenóis e minerais importantes, o que os tornam excelentes para o uso na indústria de alimentos, farmacêutica e biotecnológica (Farias, *et al*., 2020; Seraglio *et al*., 2018).

Geralmente, os frutos das espécies da família *Myrtaceae* apresentam formato oblongos ou redondos com medidas entre 1,25 e 3 cm de comprimento, com epicarpo fino, liso, brilhante, aderente, de cores variadas indo do verde à púrpura profunda, em fase de maturação inicia-se em tons de verde e quando maduros apresentam características próprias e sabor adocicado, as arvores variam entre 10 e 20 m de altura e aproximadamente 60cm de diâmetro, suas folhas são verdes e opostas, membranáceas, ovalado-oblongas, medindo de 4-10 cm de comprimento por 3-4,5 cm de largura, (Farias *et al.*, 2020; Vallilo *et al.*, 2008).

Dentre o vasto número de espécies da família *Myrtaceae* o gênero *Campomanesia* se destaca devido à sua rica composição fitoquímica que oferece uma infinidade de benefícios para o consumo humano, que pode ser realizado *in natura* ou implementado na indústria de alimentos, farmacêutica e bioquímica. Suas flores são indicadas como melíferas e sua madeira utilizada em produção de instrumentos e atividades agrícolas tornando-a uma espécie de alto potencial econômico (Ferreira; Kempka, 2023; Vallilo *et al*., 2008). Estudos mostram a aptidão de espécies *Campomanesia* no tratamento farmacológico de febre, disenteria e doenças do trato urinário (Sant'anna *et al.*, 2017). Umas das espécies do gênero, a *Campomanesia xanthocarpa* Berg, popularmente conhecida como guabiroba, espécie nativa brasileira é investigada no presente estudo (Barbieri, et al., 2018).

3 GUABIROBA (*CAMPOMANESIA XANTHOCARPA O.* BERG)

A *Campomanesia xanthocapa.* (Berg), espécie de arvore frutífera que ocorre em florestas com altitudes <2.000m acima do nível mar, distribuídas nas florestas da Colômbia, Equador, Brasil e Peru, raramente possui cultivo em pomares doméstico e seu fruto pode ser consumido in natura ou processado (Lima *et al.*, 2016). É popularmente conhecida no Brasil como Guabiroba, Guabiroba do campo, Guavirova, Guabirobeira do mato, no Peru como Palillo e na Colômbia como Guayavo de Anselmo ou Guayava palo (Barbieri *et al*., 2017; SI *et al*., 2017).

A Guabirobeira (figura 1) é uma planta de ampla distribuição no território nacional, encontrada com maior frequência em regiões Sul, Sudeste e Centro-Oeste, cujo bioma é característico de Mata Atlântica e o Cerrado predomina, a incidência ocorre desde o estado de Minas Gerais até o extremo do rio Grande do Sul (Alves *et al*., 2013; Teleginski *et al*., 2018). Seu florescimento acontece de agosto a setembro e a frutificação de novembro a dezembro, seu fruto é característico e apresenta coloração amarelo-esverdeado, arredondado, possui uma fina casca que envolve uma polpa esbranquiçada e diversas sementes (Alves *et al*., 2013; Vallilo *et al*., 2006).

Figura 1 - Imagens da arvore, folhas, flores e fruto da Guabiroba (*campomanesia xanthocarpa.* berg):

A saber; A) Arvore de porte adulto, B) Folhas, C) Flores e D) fruto maduro.

Fonte: Myrtaceae — A Lista de Plantas, (2013)

A guabiroba é um fruto pequeno do tipo baga medindo entre 2 a 3cm de comprimento, globoso, em estado de maturação apresenta epicarpo amarelo liso e fino, contendo polpa suculenta de sabor e aroma característico com 1 a 32 sementes, pesa em média 6g, composta por 55% de mesocarpo, 10% de endocarpo, 13% de sementes, 3,9% de cálice e 18% de epicarpo, há estudos que indicam que 60% do fruto é polpa (Farias *et al*., 2019; Santos *et al*., 2009).

O fruto da guabirobeira apresenta potencial significativo como um alimento funcional devido às suas características nutricionais de elevado valor. A guabiroba é rica em carboidratos (7,8-10,2%), fibra alimentar (4,1-9,8%), apresenta proteínas (1,0-1,1%), lipídeos (0,7-1,9%), vitamina C e vitamina B12 (Barbieri *et al*., 2018; Barbieri *et al*., 2017). Estudos indicam que as folhas e extratos do fruto apresentam atividades medicinais, anti-inflamatórias e antioxidantes (Klafke *et al.*, 2015). Quanto a composição nutricional da guabiroba, pesquisa aponta que o fruto apresenta elevado teores de umidade, baixa densidade energética, altas concentrações de potássio e alta quantidade de fenólicos totais (Vallilo *et al.*, 2006). Esses autores relatam que além disso, a guabiroba se destaca em relação aos compostos antioxidantes quando comparado com outras frutas provenientes do cerrado brasileiro.

O contínuo processo de modernização de tecnologias sustentáveis permite que polpas de frutas silvestres sejam utilizadas no processamento de produtos alimentícios e cosméticos mais eficazes. Nos últimos anos há registros do uso de polpa de guabiroba no processamento de geleia, filmes comestíveis e variadas aplicações na indústria (Curi *et al*., 2019; Kowalska *et al*., 2017; Silva-rodrigues *et al*., 2020). O quadro 1 apresenta alguns estudos variados com uso de partes da guabirobeira.

Quadro 1 - Estudos realizados com partes da guabirobeira (*Campomanesia xanthocarpa)*

Parâmetro avaliado	**Parte da Guabiroba**	**Resultados**	**Referência**
Comparação de *Campomanesia xanthocarpa* com ácido acetilsalicílico (AAS) nos parâmetros inflamatórios	Folhas	*Campomanesia xanthocarpa* apresentou melhores resultados anti-inflamatório e antioxidante em comparação com ácido acetilsalicílico (AAS)	(Klafke *et al.*, 2016)
Investigação dos efeitos do extrato aquoso de *C. xanthocarpa* na pressão arterial de ratos normotensos	Folhas	A administração aguda do extrato aquoso de *C. xanthocarpa* tem efeito hipotensor dose-dependente em ratos normotensos.	(Sant'anna *et al*., 2017)
Determinação do potencial genotóxico e mutagênico e potenciais efeitos protetores contra danos oxidativos.	Folhas	Mutações frameshift e oxidativas foram observadas apenas na ausência de ativação metabólica, mostrou efeitos protetores contra danos oxidativos no DNA associados à presença de ácido elágico e não induziu mutagenicidade *in vivo*	(Aires *et al.*, 2019)
Potencial tecnológico da polpa congelada, extrato de suco, elaboração de doce em massa, extração de pectina a parti da polpa e óleo da semente	Fruto, polpa, extrato do suco e semente	A apresentou durante o armazenamento (128 dias) 90% de compostos fenólicos totais, 94,65% dos flavonoides; 76,48% do teor de vitamina C e 77,02% do teor de carotenoides totais. A utilização de enzimas visando ao aumento da extração de suco foi efetiva e apresentou boa retenção	(Santos., 2011)

		dos compostos bioativos e considerável potencial antioxidante. O doce apresentou considerável valor nutricional, capacidade antioxidante e boa aceitação sensorial. E o óleo extraído da semente Através de processos de extração por solventes foi obtido um produto rico em ácido oleico (60,84%) e linoleico (14,15%)	
Comportamento reológico de geleia da polpa de guabiroba	Fruto	A polpa apresentou ultraestrutura heterogênea formada por malha compacta e interface porosa de fibras, comportamento de gel e instabilidade térmica na faixa de 5 a 95 °C. A geleia apresentou tensão de escoamento mínima para iniciar o escoamento e tensão cisalhamento descrito pelo modelo Herschel-Bulkley e o comportamento típico de gel não foi afetado pelo período de 22 meses.	(Barbieri *et al.*, 2018)
Composição polifenólica e atividade biológica por meio de cromatografia líquida bidimensional abrangente (LC × LC)	Fruto	Maior extração de compostos realizada com solução de ácido acético a 2% e acetonitrila (50:50, v/v), total de 37 compostos diferentes encontrados. Os frutos apresentaram atividades antidiabéticas e antioxidantes com alto potencial como parte estratégica dietéticas para estágios iniciais de diabete tipo 2.	(Grutzmann *et al.*, 2020)
Uso da pectina de guabiroba na revelação de filmes	Fruto	Os filmes de pectina de gabiroba demonstraram alta resistência e rigidez, o	(Dias *et al.*, 2024)

e comparar pectinas comerciais de citros e de gabiroba purificadas e parcialmente esterificadas, todas elas reticuladas com íon cálcio .		que permite o uso da pectina do fruto como alternativa fonte para obtenção de filme resistentes.	
Avaliação fotoprotetora e antioxidante da casca de frutos para a aplicação em alimentos e cosméticos.	Fruto(casca)	Foi verificada a presença de níveis relevantes de metabólitos secundários (alcaloides, compostos fenólicos, flavonóides, glicosídeos e taninos) sendo os composto fenólicos mais abundantes. O extrato apresentou potencial antioxidante, antimicrobiano e fotoprotetor.	(Luis *et al.*, 2023)

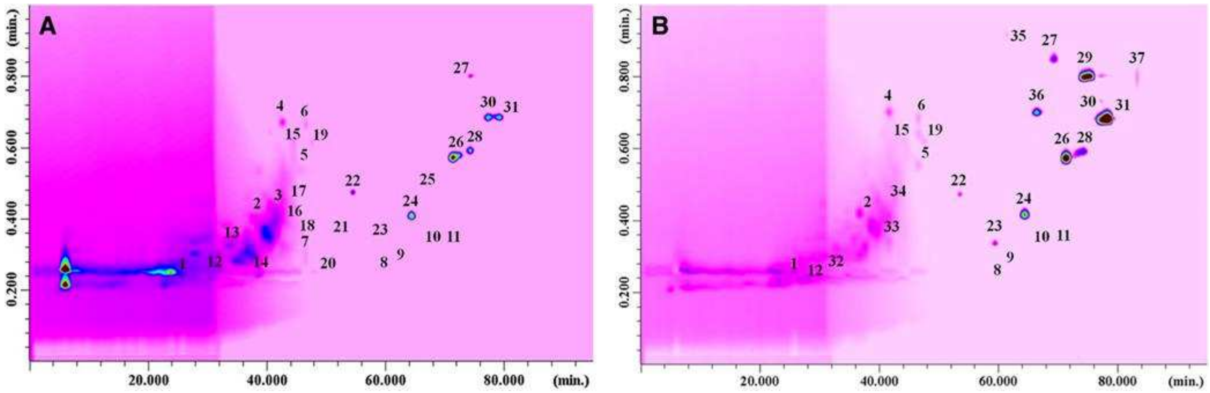
Fonte: elaborado pelo autor (2025).

Estudos realizados com extratos da casca de guabiroba, usado para prevenir oxidação lipídica de patê de tilápia durante diferentes tipos de armazenamentos refrigerado, apresentaram resultados positivos para a redução efetiva da oxidação quando comparado com aditivos, nesse estudo foi possível identificar a catequina como mais abundante, seguida do ácido gálico e epicatequina, consequentemente a presença desses compostos comprovam a capacidade antioxidante da guabirbora como prevenção da oxidação lipídica (Da *et al.*, 2023). Já Rodrigues *et al.*, (2020) analisaram o emprego da polpa de guabiroba como reforço em filme comestível de arroz sem glúten e identificaram que concentrações de 10 a 15% de polpa apresentaram melhorias tração de até 48,8% e total degradação em 45 dias.

O constante aumento de estudos sobre a utilização da polpa de guabiroba é perceptível. Prestes *et al.* (2021) analisaram a incorporação da polpa de guabiroba em leite fermentado para avaliar a capacidade antioxidante em condições de simulação gastrointestinal *in vitro* e identificaram que a adição de 10% de polpa ao fermentado aumenta a taxa de sobrevivência e contagem de células viáveis de *Lactobacillus bulgaricus* e *Streptococcus thermophilus* em todos os estágios da simulação gastrointestinal. Esses autores apontam que o uso da polpa de guabiroba apresenta alto potencial funcional e elevadas propriedades fitoquímicas no desenvolvimento de produtos alimentícios. Silva e Kempka (2023), afirmam que estudos como esses abrem as postas para o campo de alimentos funcionais naturais como a guabiroba.

Na literatura é possível identificar estudos promissores com o uso do fruto. A fim de mitigar a ação quimioprotetora de extrato de guabiroba na recuperação da indução de estresse oxidativo em células de *Saccharomyces cerevisiae* causadas por H_2O_2, Grutzmann *et al.*, (2020) analisaram a ação de proteção exercida do pré-tratamento do extrato de guabiroba e identificaram que amostras tratadas suprimiram até 71% do dano causado por H_2O_2 para o extrato do fruto maduro e 61% para o fruto verde (figura 2).

Figura 2 - Diagramas de contorno (280 nm) obtidos usando a metodologia LC×LC otimizada para análise de extratos de guabiroba.



A saber: A) Pré-tratamento com extrato do fruto verde e B) Pré-tratamento com extrato do fruto maduro.

Fonte: Grutzmann Arcari *et al.*, (2020)

O mesmo estudo apresentou inibição de α-amilase e α-glicosidase, ou seja, estratégias dietéticas com o uso de guabiroba são potencialmente ideais para o tratamento de estágios iniciais de diabetes tipo 2 e complicações associadas. É evidente a necessidade sobre o conhecimento das características dos componentes físico-químicas, a identificação e quantificação na polpa de guabiroba.

2.1 COMPONENTES FÍSICO-QUÍMICOS DA GUABIROBA (*CAMPOMANESIA XANTHOCARPA O. BERG).*

O conhecimento sobre a composição físico-química da *Campomanesia xanthocarpa* é essencial. A tabela 1 apresenta resultados de estudos encontrados na literatura sobre sua composição.

Tabela 1 - Composição físico-química da guabiroba

Parâmetro analisado	(Pereira, *et al*., 2012)	(A. M. Alves et al., 2013)
	($g.100^{-1}$)	($g.100^{-1}$)

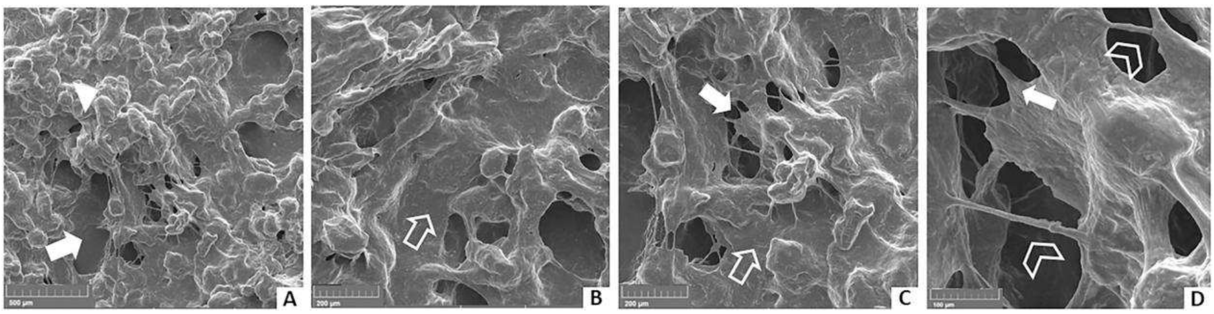
Umidade	82,21	80,87
Cinzas	0,47	0,43
Proteínas	5,53	1,06
Lipídeos	3,7	0,55
Carboidratos	15,68	10
Açucares totais	22,74	*
Açucares redutores	18,6	*
Fibras insolúveis	*	5,6
Fibras alimentar solúveis	11,55	1,49
Fibra alimentar total	11,95	7,1

*Parâmetro não analisado no estudo

Estudos encontrados na literatura apresentam diversos resultados acerca da composição nutricional da guabiroba. Pereira *et al*, (2012) analisaram três frutos diferentes da família *Myrtaceae* e identificaram que a polpa de guabiroba apresenta 3 vezes mais carboidratos e destaque para o teor lipídico com 2 a 7 vezes mais que os resultados encontrados para goiaba amarela e uvaia. O mesmo estudo verificou que a polpa de guabiroba está na faixa recomendada de teor de sólidos solúveis totais. Isso significa que produtos a partir da polpa podem apresentar sabor mais agradável e natural dado que valores elevados desse constituinte necessita de menor adição de açucares, diminuição do tempo de evaporação da água, menor gasto energético e bom rendimento do produto.

Segundo Barbieri *et al* (2018), a polpa de guabiroba apresenta 17,7% ± 0,8 de sólidos solúveis totais que se deve principalmente a presença de fibras, sendo a pectina mencionada. Esse estudo foi capaz de verificar a sedimentação da polpa pura e a relação polpa:água nas proporções de 1:1 a 1:30 e constataram que a concentração 1:1 não apresentou precipitação após o período de sedimentação avaliado e atribuiu ao teor de fibras (porção insolúvel) identificado no estudo após análise da interfase porosa na ultraestrutura da superfície da polpa de guabiroba obtida por MEV.

Figura 3 - microscopia eletrônica de varredura (MEV) para a polpa de gabiroba. A imagem (A) mostra uma imagem panorâmica. A imagem (B) mostra uma maior ampliação da área mais densa. As imagens (C) e (D) mostram a área de menor densidade com perfurações características e presença de fibras.



Fonte: Barbiere *et al* (2018)

O mesmo autor em estudos posteriores constatou por meio de medidas reológicas dinâmicas que a pectina extraída da polpa de guabiroba em concentração de 5% (p/v) contribuem para o comportamento do gel e apresenta comportamento de afinamento por cisalhamento em água e em 0.1 mol L^{-1} NaCl (Barbieri *et al.*, 2019). Esses estudos apresentam as características químicas e reológicas de macromoléculas como a pectina e viabilizam informações para uso posteriores em várias aplicações. É bem sabido que a composição nutricional (tabela 1) da polpa de guabiroba apresenta alta variação de componentes, no entanto, assim como demais frutos da família *Myrtaceae* ela depende de condições climáticas, de solo, manejo e nutrição dos pomares, maturação e variedade dos frutos (Santos *et al.*, 2013; Vallilo *et al.*, 2008).

2.1.1 Componentes bioativos.

A composição fitoquímica da guabiroba é variada, o fruto tem uma alta variabilidade de componentes bioativos presentes em sua matriz, seja no fruto, na polpa, na folha, ou no resíduo. Segundo Silva e Kempka (2023), a *Campomanesia xanthocarpa* O. BERG é um fruto rico em compostos bioativos distintos que exibem capacidade antioxidante, que por sua vez pode desempenhar um papel importante contra doenças causadas pelo estresse oxidativo no corpo. Para Raphaelli *et al* (2021), a guabiroba tem alto potencial para o uso em formulações na indústria alimentícia e farmacêutica devido ao grande número de compostos bioativos presentes em suas partes (frutos, folhas, polpa e resídiuo). Vale ressaltar que Pereira *et al* (2012), consideraram frutos da família *Myrtaceae* e identificaram que a guabiroba pode apresentar mais que o dobro de compostos fenólicos totais quando comparada com outras frutas da mesma família. A tabela 2 apresenta alguns estudos encontrados na literatura sobre a composição bioativa da polpa de guabiroba.

Tabela 2 - Compostos bioativos da polpa de guabiroba

Bioativos	Polpa			
	(Alves *et al.*, 2013)	(Capeletto *et al.*, 2016)	(Santos *et al.*, 2013)	(Pereira, et al., 2012)
Compostos Fenólicos Totais (GAE)/100g	903,19	68,58	131,9	*
ABTS (µM Trolox/g)	507,49	*	109,9	*
DPPH (mg TEAC/100g)	161,29	*	70,67	378,3 (g/g DPPH)
Vitamina C ($mg.100g^{-1}$)	0,3	*	313,21	*

Flavonoides totais ($mg.100g^{-1}$)	*	8,1	67,94	*
Carotenoides ($\mu g.100g^{-1}$)	*	*	283,31	*
ORAC [1] (µmol/l TEAC/g)	*	*	*	229

Fonte: Elaborado pelo autor (2025).

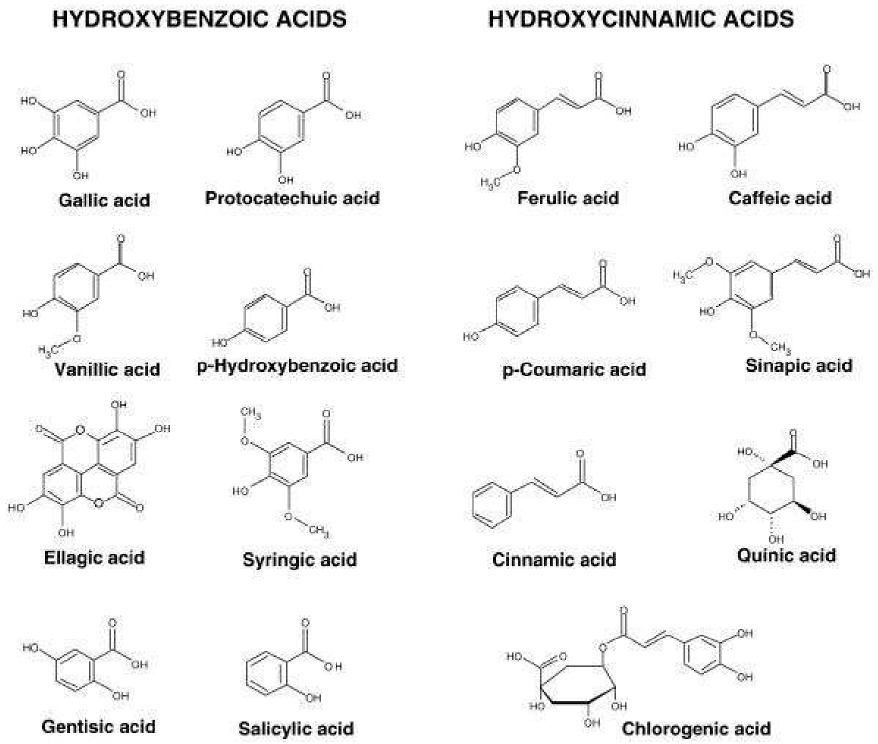
Esses estudos apontam resultados relevantes, insight para o uso da polpa de guabiroba como uma matéria prima funcional com alta capacidade antioxidante *in vitro* contra ABTS (ácido 2,2′-azino-bis(3-etilbenzotiazolina-6-sulfônico), DPPH (2,2-difenil-1-picrilhidrazil) e apresentam elevados teores de compostos fenólicos, vitaminas e carotenoides.

2.1.2 Compostos fenólicos

Silva e Kempka (2023) relatam que os compostos fenólicos totais desempenham um papel fundamental para a proteção contra radiação ultravioleta, crescimento, reprodução, resistência à patógenos e pigmentação das plantas. Esses mesmos autores relatam que esses compostos são anéis aromáticos com grupos hidroxilas em sua estrutura e são amplamente encontrados nos tecidos vegetais. Kelly e O'Mahony (2019), relataram que os compostos fenólicos incluem como suas principais classes os ácidos fenólicos, flavonoides, lignanas e taninos. Esses autores relatam que esses componentes apresentam alta capacidade redox e que são importantes antioxidantes capazes de atuar como doadores de hidrogênio, agentes redutores e sequestradores de oxigênio singlete no organismo.

Segundo Martins *et al* (2011), os ácidos fenólicos naturais podem ser divididos em: àcidos hidroxibenzóicos e hidroxicinâmico (figura 4). Essa divisão dar-se de acordo com a estrutura de cada grupo.

Figura 4 - Ácidos fenólicos naturais

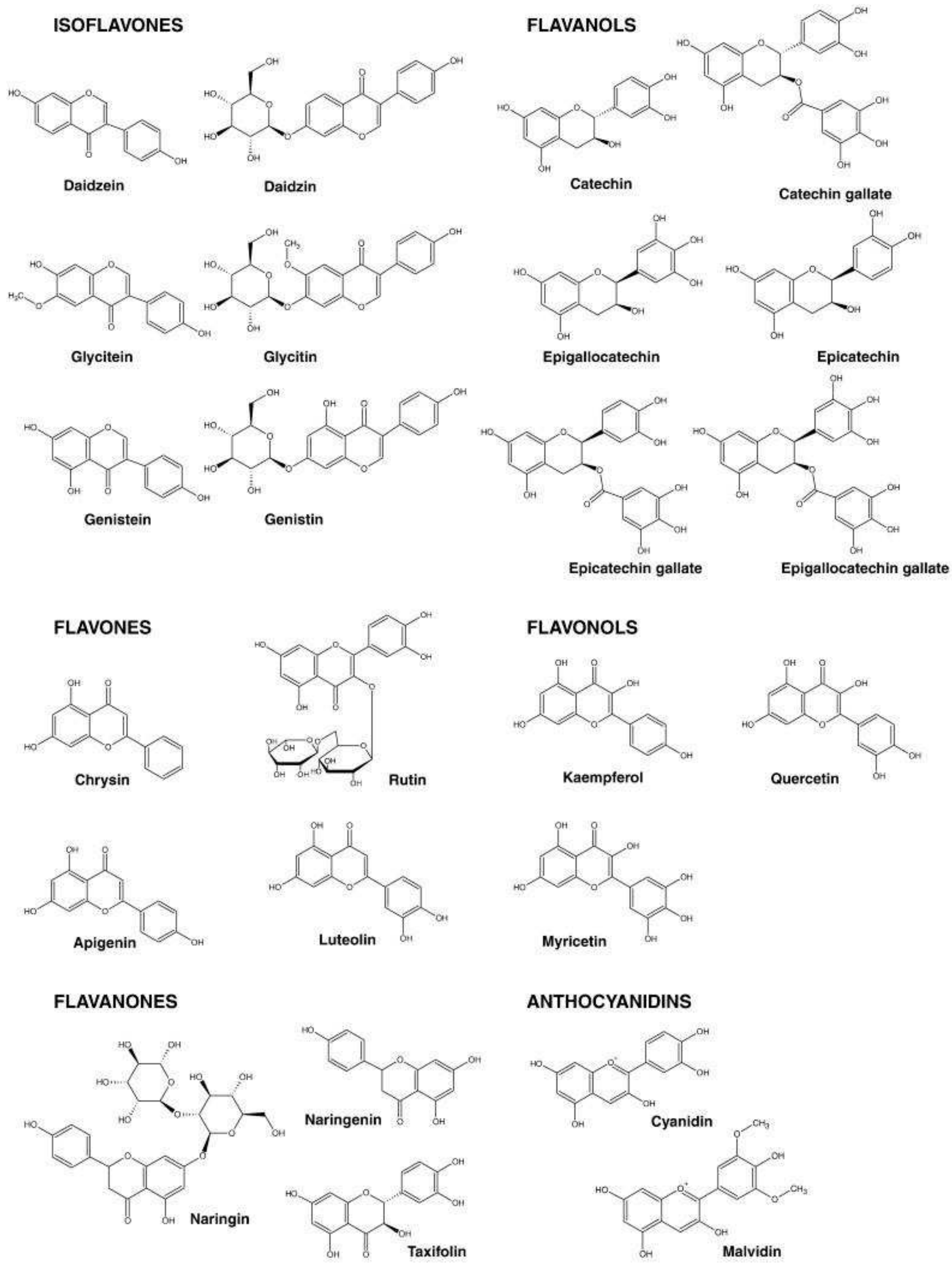


Fonte: Martins *et al* (2011).

Muitos desses ácidos fenólicos são encontrados na guabiroba devido a biodisponibilidade e a composição fitoquímica dos frutos. Castanha *et al* (2023), identificaram e quantificaram alguns desses componentes na folha da guabiroba. Esses autores identificaram 4 ácidos hidroxibenzóicos e 4 hidroxicinâmico, sendo ácido gálico (63,80 mg Kg^{-1}), ácido protocatecuico (150,0 mg Kg^{-1}), Ácido siríngico (0,32 mg Kg^{-1}), ácido salicílico (4,04 mg Kg^{-1}) e ácido cafeico (3,98 mg Kg^{-1}), ácido clorogênico (39,65 mg Kg^{-1}), ácido ferúlico (4,30 mg Kg^{-1}) e ácido p-cumárico (7,67 mg Kg^{-1}), respectivamente.

Os flavonoides (figura 5) apresentam estrutura química caracterizada por dois anéis aromáticos conectados por três carbonos tipicamente formado por um anel heterocíclico oxigenado, constituem o maior grupo de fenólicos vegetais, o que representa mais da metade dos 8 mil (Silva; Kempka, 2023; Martins et al., 2011). Esses mesmos autores relatam que a guabiroba tem na composição flavonoides como miricetina , quercetina e kaempferol que podem ser encontrados em partes da *Campomanesia Xanthocarpa.*

Figura 5 - Flavonoides naturais



Fonte: Martins *et al* (2011).

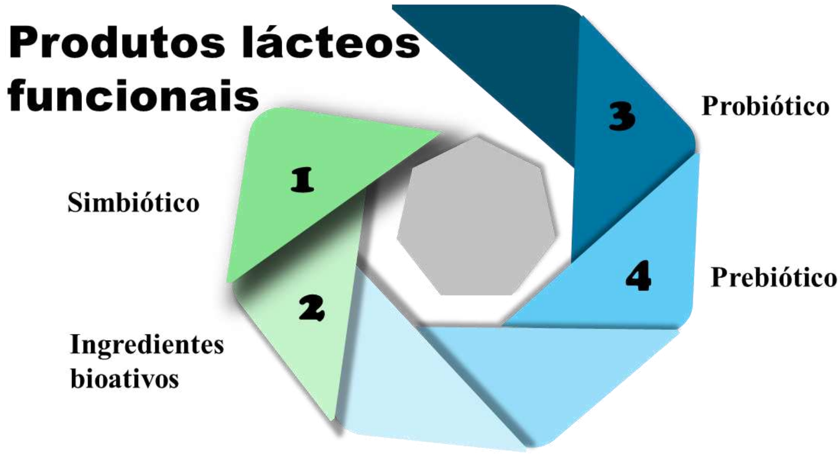
Segundo Martins *et al* (2011), as alterações nos padrões de substituição do anel C na estrutura molecular desses compostos são determinantes para a formação das principais classes de flavonoides, como flavonóis, flavonas, flavanonas, isoflavonas e antocianinas. Castanha *et al* (2023), relatam a presença dos flavonoides como Apigenina (0,07 mg Kg $^{-1}$), Catequina (1,13 mg Kg $^{-1}$), Coniferaldeído (0,08 mg Kg $^{-1}$), Epicatequina(1,20 mg Kg $^{-1}$), Galato de epigalocatequina (0,21 mg Kg $^{-1}$), Isoquercitrina (57,75 mg Kg $^{-1}$) Campferol (18,55 mg Kg $^{-1}$), Luteolina(0,01 mg Kg $^{-1}$), Naringina(0,05 mg Kg $^{-1}$), Quercetina (21,31 mg Kg $^{-1}$), Rotina (39,12 mg Kg $^{-1}$), Sinapaldeído (0,56 mg Kg $^{-1}$) e Siringaldeído(0,28 mg Kg $^{-1}$) na folha da guabirobeira. Esses autores mencionam que os fenólicos predominantes na *Campomanesia Xanthocarpa* incluem ácidos fenólicos, como ácido benzoico, protocatecuico, gálico, clorogênico e 2,5-di-hidroxibenzoico, além de flavonoides do subgrupo flavonóis, representados por isoquercitrina, rutina, quercetina e kaempferol. A presença desses compostos é um fator primordial para que o uso da polpa de guabiroba em produtos lácteos obtenha resultados satisfatórios na melhoria das características nutricionais e funcionais do derivado estudado.

4 PRODUTOS LÁCTEOS

Para Feil *et al* (2020), o leite e os produtos lácteos constituem um alimento globalmente essencial para a humanidade, pois fornecem proteínas e minerais essenciais ao crescimento, manutenção da saúde humana e são um dos produtos mais consumidos no mundo devido às suas características especificas. De cordo com o Ministério da Agricultura e Pecuária (2024), o Brasil é detentor da terceira maior produção de leite do mundo (34 milhões de litros por ano) isso equivale a 98% dos municípios do território nacional produzindo em pequenas e médias propriedades. Esses números são fundamentais para a indústria, uma vez que a produção de derivados está diretamente associada à disponibilização do leite.

As propriedades nutricionais do leite o tornam uma excelente matéria prima. Além do consum, vários derivados também apresentam produção e alta demanda em todo o mundo há milênios. Visioli e Strata (2014) relatam que os produtos lácteos têm sido objeto de vários estudos devido ao impacto positivo na saúde humana, tanto pelo consumo de produtos integrais quanto em seus componentes isolados. O aumento do consumo de alimentos com propriedades que vão além das convencionais tem despertados interesse em especialistas da área de nutrição, ciência alimentar e pelos consumidores. A produção de lácteos acrescidos de bioativos sejam de origem vegetal ou microbiana tem sido objeto de estudo. Adinepour *et al.* (2022) relatam que a fortificação de lácteos com propriedades bioativas apresentam novas características biológicas e melhor aceitação dos consumidores. Produtos lácteos enriquecidos de componentes biológicos, que podem apresentar benefícios para o consumidor, são ditos como produtos lácteos funcionais. Bouarab et al (2019) mencionam que os produtos funcionais são alimentos que contém compostos bioativos como polifenóis, carotenoides, vitaminas e/ou microrganismos benéficos à saúde do consumidor (Figura 6).

Figura 6 - visão esquemática de produtos lácteos funcionais



Fonte: adaptado de oliveira (2011).

Produtos lácteos têm despertado interesse considerável em todo o mundo, os benefícios desses alimentos mostram o potencial da adição de bioativos para a melhoria nutricional. A composição química dos derivados lácteos em combinação com extratos ricos em bioativos e/ou a adição de microrganismos probióticos, prebióticos e simbióticos pode aumentar a biodisponibilidade de fitoquímicos e peptídeos presentes na fração desses alimentos, que são essenciais para a nutrição humana (Anusha *et al.*, 2024; Myazaki *et al.*, 2020)

5 PRODUTOS LÁCTEOS FUNCIONAIS

A partir de estudos relacionados ao consumo de derivados do leite, pesquisas apontam que esses produtos têm mostrado aumento na demanda pelo consumo devido serem uma fonte de compostos funcionais que podem contribuir para a manutenção da saúde humana e podem incluir o aumento da função imunológica, menor risco de hipertensão, ausência de doenças cardiovasculares, redução da pressão arterial, prevenção de infecções gastrointestinais e a melhoria do desempenho físico (Cifelli, 2021; Lin *et al.*, 2021).

A indústria alimentícia tem estudado cada vez mais a promoção de melhorias nas características nutricionais e funcionais dos produtos lácteos Balthazar *et al.*, (2019). A adição de aditivos ricos em compostos bioativos apresenta resultados relevantes para fontes oriundas de polpas de frutas nativas brasileiras (Prestes *et al.*, 2021). A adição de frutos da família *Myrtaceae* em produtos lácteos tem apresentado bons resultados devido ao elevado teor de bioativos e capacidade antioxidante. A polpa de *Campomanesia xanthocarpa* O. Berg (Guabiroba) devido às suas características nutricionais a tornam adequada para uso como matéria prima para o enriquecimento nutricional e funcional de láteos (Coradin *et al*., 2011; Pereira, *et al*., 2012; Nascimento *et al*., 2019).

De acordo com a perspectiva de Myazaki *et al* (2020), é grande a importância dos estudos que buscam analisar as interações dos componentes do leite com bioativos, dado que essa interação entre os fitoquímicos do extrato e a matriz do leite podem sofrer alterações e afetar a bioatividade, biodisponibilidade e as características sensoriais deles. Sabe-se que a adição de bioativos é um fator importante para a melhorias das características nutricionais e funcionais dos produtos lácteos. O quadro 2 apresenta variadas aplicações de bioativos em produtos lácteos.

Quadro 2 – Produtos lácteos funcionais enriquecidos com bioativos

0	Composto bioativo adicionado	Principais conclusões do estudo	referência
Leite fermentando	Polpa de guabiroba (*Campomanesia xanthocarpa.* O BERG)	A polpa contribuiu para maior multiplicação e sobrevivência de *Bifidobacterium* BB-12, L. *bulgaricus* e *S. thermophilus* em uma simulação gastrointestinal *in vitro*	(Prestes *et al.*, 2021)
Ricota Funcional	Enriquecimento de fitosteróis	O consumo de 100g fornece a quantidade necessária de fitosteróis, melhora os benefícios funcionais e é uma nova alternativa para indivíduos que controlam seu colesterol LDL no sangue	(Nzekoue *et al.*, 2021)
Queijo tipo Caciotta	Groselha preta (*Ribes Nigrum)* e Cereja Cornalina (*Cornus Mas)*	Aumento dos bioativos sem alterar a avaliação sensorial; os polifenóis não causaram efeito negativo nos LAB e	(Foligni et al., 2023)

		não alterou negativamente as características físico-químicas analisadas.	
Bebida láctea e sobremesa láctea	Substituição do cacau em pó por farinha da casca do cacau	Aumento significativo da capacidade antioxidante e compostos fenólicos totais, boa aceitação sensorial	(Barros *et al.*, 2023)
Queijo minas frescal	Extrato de mesocarpo de coco babaçu	Não alterou a denominação do queijo e apresentou capacidade antimicrobiana.	(Lima *et al.*, 2024)
Bebida fermentada láctea funcional	Polpa de guabiroba	Potencial probiótico, 1,6 vezes mais compostos fenólicos e aumento de 164% de carotenoides (β-caroteno, α-caroteno, γ-caroteno, e β-cryptoxantina	(Prestes *et al.*, 2023)
Bebida láctea funcional	Polpa de Kiwi e Óleo de Gergelim	Uma bebida com alta capacidade antioxidante, com alto teor de compostos fenólicos, além de apresentar-se como uma bebida rica em vitaminas, minerais e alto nível de PUFAs	(El-Sayed, Salama e El-Sayed, 2015)
Queijo processado inovador	Polpa de mamão	Melhorias nos atributos físico-químicos, sensoriais e o aumento de vitaminas (K, C, A), minerais (K), compostos fenólicos totais e β-caroteno	(El-Loly, Farahat e Mohamed, 2024)
Queijo do Himalaia	Fruta *Withania Somnifera*	O extrato aumento significativamente a estabilidade lipídica, características sensoriais, qualidade microbiana, valor funcional.	(Sharma *et al.*, 2023)

Iogurte	Partes do pinhão (falha, casca e amendo) com açaí.	Aumento de proteínas, fibras, capacidade antimicrobiana para formação de biofilme, aumento dos polifenóis totais, alta capacidade antioxidante e aumento dos níveis de minerais (Ca, Fe, K, Na e P)	(Sbruzzi Fiebig *et al.*, 2024)

Fonte: Elaborado pelo autor

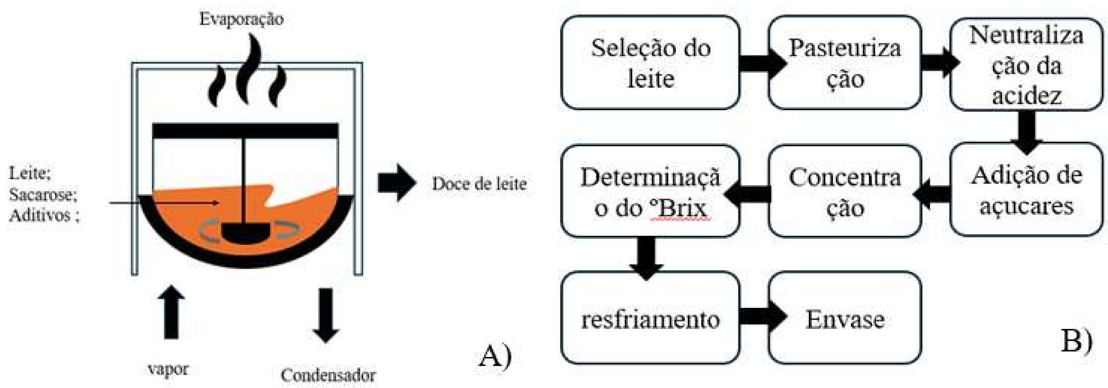
A versatilidade nos processos de adição desses extratos em produtos lácteos é comumente associados à saúde, possuem valor acessível e *shelf-life* elevado (Carneiro *et al.*, 2012). Estudos recentes indicam *insight* promissores para o desenvolvimento de produtos lácteos funcionais adicionados de bioativos (bebidas lácteas, queijos, doces lácteos, creme , manteiga, iogurte) (Anusha *et al.*, 2024; Cobos *et al.*, 2024; El-Loly; Mohamed, 2024; El-Sayed; El-Sayed, 2015; Mohammed; Hilmi, 2024; Nikolić *et al.*, 2024; Sbruzzi *et al.*, 2024; Silva *et al.*, 2024). Esses autores relatam que produtos lácteos apresentam maior afinidade, bioatividade e biodisponibilidade quando adicionados de extratos ricos em compostos bioativos e que a composição nutricional e funcional varia de acordo com a fonte do extrato. A partir dessa perspectiva, o uso de bioativos em produtos como doce de leite e queijos frescos que apresentam alta demanda pode ser promissor, dado que a adição extratos pode contribuir com melhorias na qualidade nutricional e funcional.

5.1 DOCE DE LEITE.

Dulce de leche, típico da América latina e popularmente conhecido no Brasil como doce de leite. É o resultado da mistura de leite e açúcar aquecidos sob condições controladas tendo como produto uma pasta caramelizada de cor e aroma característicos (Os et al., 2021). Esse derivado é o resultado da concentração do leite à pressão atmosférica adicionado de sacarose e/ou outros ingredientes, possui alto valor energético e condições proteicas, minerais e carboidratos relevantes (Figueroa et al., 2024). No Brasil o doce de leite é regulamentado pela Portaria 354 de 1997 a qual o classifica como; Produto com ou sem adição de aditivos, obtidos pela concentração do leite ou leite reconstruindo, podendo haver adição de sólidos de origem láctea ou creme adicionado de sacarose (Brasil, 1997). Essa mesma portaria relata que o doce de leite deve apresentar consistência cremosa ou pastosa, sem a presença de cristais perceptíveis, conter entre 5 e 30% de ingredientes opcionais, possuir cor castanho caramelizado e ter no máximo 30% de umidade, matéria gorda entre 6 e 9%, cinzas máximos de 2% e o mínimo de 5% de proteínas.

O processamento e a composição do Doce de leite variam de acordo com o país em que é produzido e comercializado, podendo apresentar diferentes condições e/ou denominações (Os et al., 2021). No México é a concentração obtida com o leite de cabra, e em cuba o doce apresenta maior concentração de sólidos solúveis totais e é comercializado em pequenas barras ou tabletes (Penci & Marín, 2016). Vale ressaltar que a produção pode ocorrer em sistemas como tachos por bateladas, tachos de forma contínua, evaporador tubular ou em tacho a vácuo. Mas todos os sistemas apresentam o mesmo princípio: a evaporação da água por aplicação direta de calor. Sendo que o tacho por bateladas (Figura 7- A) é o trocador mais usado e o processamento é realizado em 8 etapas (Figura 7 -B) (Pacheco & Júnior, 2020).

Figura 7 - Evaporador e fluxograma usado para o processamento de Doce de leite



A saber; A) Tacho trocador de calor e B) Fluxograma de processamento.

Fonte: elaborado pelo autor 2025.

As características sensoriais como aroma, textura e cor do doce de leite são diretamente associadas aos parâmetros de produção (tempo e temperatura) e os ingredientes usados no processamento (Os et al., 2021). Essas particularidades são atribuídas à produtos da reação de Maillard que são essenciais para o aumento do consumo e estão diretamente associados à aceitação do consumidor (Figueroa *et al.*, 2024). Todavia, é perceptível o aumento de tendências relacionadas ao consumo de alimentos que apresentem benefícios adicionais, como altos níveis de nutrientes associados ao desenvolvimento e/ou prevenção de doenças crônicas (Sagaceta-Mejía *et al.*, 2022). Vale ressaltar que esses benefícios são atribuídos à adição de componentes ricos em compostos bioativos e a interação de fitoquímicos e/ou atividade biológica relacionado à incorporação usada.

Apesar que a adição de castanhas, cereais e polpas de frutas seja permitido pela legislação, a fortificação com bioativos é complexa, devido à possíveis efeitos no produto (propriedades sensoriais como textura, aroma e aparência) e a necessidade de estudos sobre a concentração ideal desses componentes para que seja comprovado os efeitos positivos na saúde (Adinepour et al., 2022). Além disso, esses autores relatam que é importante ressaltar que a temperatura empregada no processo de concentração do doce de leite pode causar a redução ou perda da funcionalidade e/ou atividade dos bioativos adicionados. No entanto, Arruda *et al* (2016) estudaram o uso de Araticum (*Annona crassiflora* Mart.) e Cagaita (*Eugenia dysenterica* Mart.) para avalizar a aceitação sensorial de diferentes formulações de doce de leite combinados com coco ralado, suco de laranja e suco de cenoura. Esses autores obtiveram resultados com mais de 70% de aceitação, o que indica que frutas do cerrado são promissoras para o uso em doce de leite e a aceitação pelo mercado.

5.2 QUEIJOS FRESCOS.

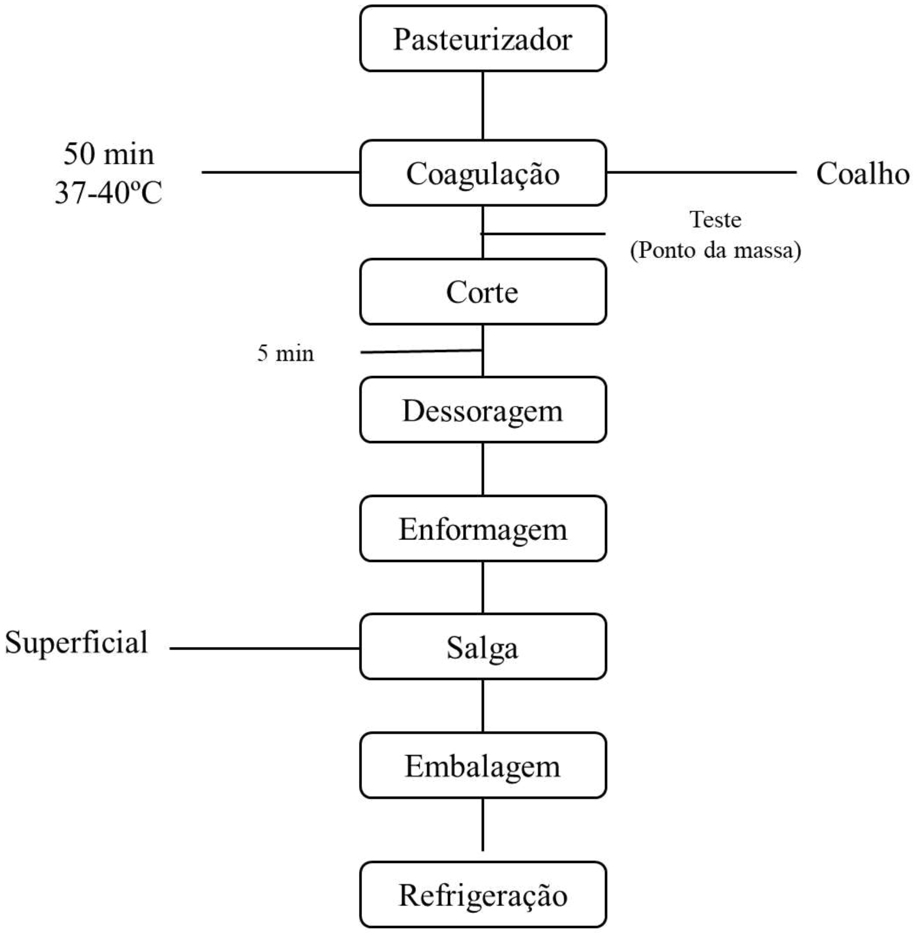
Ao buscar na literatura o termo "*Queijo fresco*" identifica-se um número expressivo de tipos do derivado. Esses derivados representa um grupo diverso com muitas variedades. São produzidos por coagulação do leite, do creme ou soro por meio de acidificação, acidificação com coalho (pequena quantidade) ou a combinação com ácido e calor (Fox et al., 2017). Esses queijos podem apresentar na sua composição substâncias alimentícias, especiarias, condimentos, aditivos, substâncias aromatizantes e materiais corantes; podem ser consumidos logo após o processamento e apresentam sabor sutil, textura cremosa, benefícios em termos de nutrição/saúde e o valor nutricional depende da produção de metabólitos de baixo peso molecular durante o processo de produção (Regulamento Técnico de Identidade e Qualidade de Queijo, 1997; Silva et al., 2019; Yu et al., 2024). Alguns desses metabólitos de pequenas moléculas são, aminoácidos, ácidos orgânicos e ácidos graxos que contribuem tanto para o sabor quanto para as funções do produto (Ma et al., 2024). Um exemplo desse tipo de queijo é o Minas Frescal.

Sabe-se que no Brasil os queijos são os principais produtos lácteos produzidos e isso representa grande parte do mercado de derivados do leite, sendo que o queijo Minas Frescal é um dos mais tradicionais e possui grande aceitação pela versatilidade do processamento e características nutricionais (Araújo *et al*., 2020; Fernandes *et al*., 2017). No geral, o queijo Minas Frescal é um produto tipicamente brasileiro, nomeado de acordo com as características e o método de produção (Araújo et al., 2020). De acordo com Brasil (1997), através da Portaria

MAPA nº 352 suas características são; um queijo brando, macio, com teor de gordura igual ou superior a 55%, produzido a parti de leite pasteurizado (73–75 °C/15–20 s) ou submetido a tratamento equivalente. Esse queijo é classificado de acordo com a Instrução normativa nº 4 de 2004 como um produto com muita alta umidade, semi-gordo, com coloração esbranquiçada, textura fechada ou aberta, com poucas olhaduras mecânicas, sabor de suave, ligeiramente mole e pode ser consumido cru (Brasil., 2004).

Para Neto (2006) a produção de queijo minas frescal se dá em 8 etapas (Figura 8). Durante a coagulação do leite a κ-caseína, encontrada na superfície das micelas de caseína, é hidrolisada enzimaticamente nas ligações peptídicas situadas entre os resíduos 105 e 106. Como resultado, a região N-terminal da molécula, conhecida como para-κ-caseína, permanece associada à estrutura da micela, enquanto a região C-terminal torna-se solúvel na fase aquosa (MUÑOZ, 2018). A partir desse processo com a presença de cálcio, pH e temperaturas adequadas ocorre a reorganização das micelas desestabilizadas resultado na formação da coalhada (Fox et al., 2017).

Figura 8 - Fluxograma de processamento de queijo tipo Minas Frescal



Fonte: elaborado pelo autor (2025).

Sharma *et al.* (2023) relatam que há a necessidade de desenvolver e/ou aprimorar alimentos como o queijo, tornando-o um alimento funcional a base da adição de frutas como *Withania* somnifera que pode influenciar diretamente nas melhorias da qualidade nutricional e funcional desse derivado. No Geral, esse estudo identificou que o extrato de *Withania somnifera* melhorou a qualidade microbiana, a estabilidade lipídica das amostras durante quatro semanas de armazenamento e a qualidade sensorial. Bem como melhorias no impacto do estresse oxidativo e aumentou significativamente ($p < 0,05$) os níveis de enzimas antioxidantes endógenas enquanto reduziu os níveis de enzimas marcadoras, peroxidação lipídica e peso relativo do fígado de ratos. Esse estudo apresenta resultados relevantes ao relacionar o uso de extratos de frutas ricas em compostos fitoquímico incorporado em queijo, o que indica o potencial desse produto lácteo como um alimento funcional de alta relevância para indústria.

Estudos recentes com o uso de subprodutos do coco Babaçu adicionado em queijo Minas fresco com menor teor de sal, indicam que o extrato do mesocarpo não foi capaz de alterar as características do produto. No geral, não ocorreu variação dos parâmetros estabelecidos pela legislação (umidade mínima 55% e 25 a 49,5% de lipídeos) e foi possível inferir que há atividade antimicrobiana relevante, associada a presença de compostos fenólicos (98,41 mg GAE/100 g) no queijo, em queijo 0,75% de NaCl e 7% de extrato (R. C. Lima et al., 2024). No entanto, vale ressaltar que esses autores identificaram que a adição do extrato do mesocarpo no queijo alterou os parâmetros de textura (Dureza) e cor (a* e b*), eles relatam que essas variações podem alterar a percepção do consumidor e gerar impacto negativo. Dessa forma é necessário estudos que possam avaliar o impacto da adição nos parâmetros de cor e textura dos queijos adicionadas de extratos de fontes de bioativos alternativas como a polpa de guabiroba.

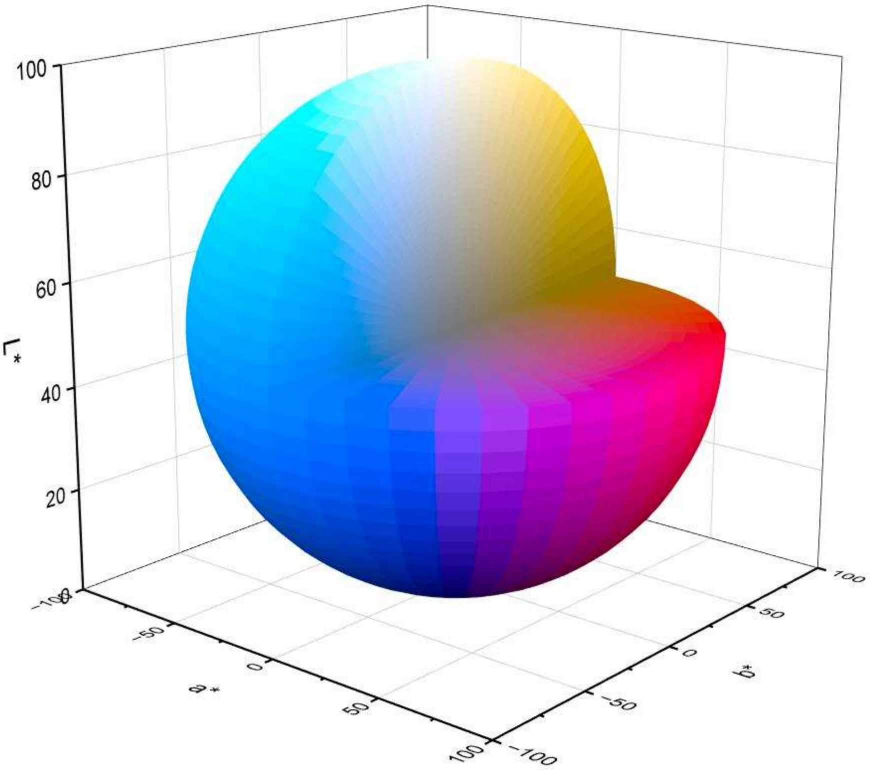
6 PROPRIEDADES FÍSICAS.

6.1 PARÂMETROS COLORIMÉTRICOS.

Dentre os parâmetros da avaliação sensorial, a cor é um dos indicadores mais significativos para a maioria dos alimentos e mudanças indesejadas podem apresentar efeitos adversos não apenas na qualidade, mas também na aceitação do consumidor (Bi et al., 2022). Para Chudy e Gierałtowska (2020), a cor dos produtos é um parâmetro importante e é relacionado à classificação de matéria-prima, entendimento de como os processos tecnológicos afetam a amostra, à avaliação da qualidade final e o monitoramento do armazenamento em produtos como o queijo. Para que seja realizada a validação dos parâmetros colorimétricos de uma amostra, é necessário o uso de calorímetro triestímulo a fim de proporciona as medições correlatadas à percepção do olho humano (Neto, 2006).

No entanto, a validação baseada em valores triestímulo é representada pelas coordenadas X, Y e Z, e não dispõem de ferramentas adequadas para estudos visando o diferenciamento das cores. Assim, um dos sistemas de medidas recomendados pelo CIE (Comission Internationale d'Eclairage) e comumente usados pela indústria de alimentos é a escala CIELAB (Figura 9) (Machado et al., 2017).

Figura 9 - Coordenadas tridimensionais do sistema de cores CIELAB

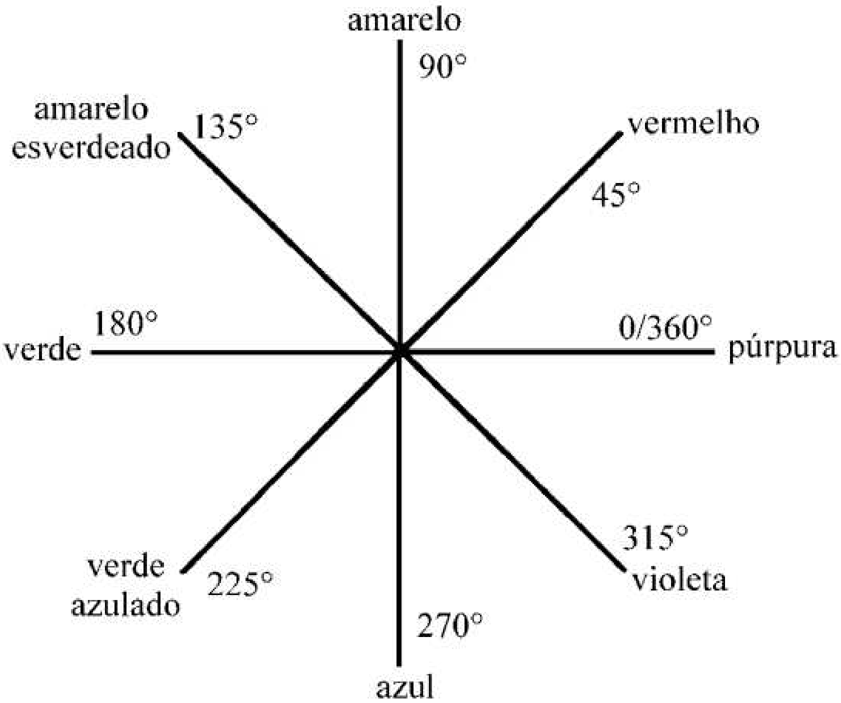


Fonte: elaborado pelo autor (2025).

Após a transformação dos valores triestímulo em eixos igualmente ortogonais; o L* representa o eixo central da luminosidade numa escala de 0 a 100 (percurso do preto ao branco); a* representa o eixo que varia entre o verde (valores negativos) ao vermelho (valores positivos); e por fim b*, que representa a variação do azul (valores negativos) e amarelo (valores positivos). (Machado et al., 2017) relatam que a intersecção dos ângulos a* e b* (0,0), correspondem ao ponto cromático e a direção perpendicular do eixo L é a tonalidade, a distância do eixo e a intensidade ou saturação. Esses autores relatam que uma cor em qualquer ponto do plano a* b* pode ser representada pela sua cromaticidade C*, que corresponde à distância até a origem acromática (0,0), e pelo ângulo de tonalidade h°, medido em graus em uma escala de 0 a 360°.

Esse ângulo é calculado no sentido anti-horário, partindo do eixo positivo de a* (vermelho, 0°), passando pelo eixo positivo de b* (amarelo, 90°), pelo verde (180°), pelo azul (270°) e retornando ao vermelho (0° ou 360°) (Figura 10).

Figura 10 - Plano de tonalidades em função de ho a* b*.



Fonte: Machato *et al* (2017).

A literatura apresenta estudos onde o uso da escala CIELAB foi usada para verificar as variações colorimétricas ocasionas pela adição de novos componentes alimentícios em produtos lácteos. Verruck *et al.* (2014) identificou que a adição de *Bifidobacterium* Bb-12 alterou os parâmetros a* e b* em queijo minas frescal de búfala armazenado em diferentes tempos de armazenamento. Prestes *et al.* (2023) identificaram variação colorimétrica visível ao olho humano ($\Delta E > 3$) após adicionar polpa de guabiroba em bebida láctea fermentada, diminuição do parâmetro L e valores positivos para a* e b*. Isso indica que a adição da polpa de guabiroba em produto lácteo, como o queijo, pode apresentar valores tendenciosos ao vermelho e amarelo, com menor luminosidade que a amostra sem a adição de polpa. Conforme apresentado no estudo citado anteriormente. Esses estudos comprovam a validação do método CIELAB como uma ferramenta eficiente para a verificação das variações de cores que podem correr após a adição de um novo ingrediente em queijos fresco e contribuem para o entendimento das características sensoriais de um novo produto.

6.2 ANÁLISE INSTRUMENTAL DE PARÂMETROS DE TEXTURA (TPA).

Um parâmetro importante a ser analisado no desenvolvimento de um produto lácteo agregado de um novo componente alimentício é a textura. Estudos relatam que a textura de alimentos é uma das características básica que influencia na aceitação, na qualidade e é atribuída pela resposta do tátil a estímulos físicos resultante do contato dos alimentos com alguma parte do corpo (Grasso et al., 2022; Tekin & Hayaloğlu, 2025). De acordo com Zhou *et al.* (2022) existe duas formas de avaliar as características estruturais: métodos sensoriais e instrumentais. No geral, os métodos instrumentais são amplamente empregados para avaliar o perfil de textura dos alimentos.

A partir da perspectiva de Mabrouki *et al* (2024), a análise de perfil de textura (TPA) é um dos métodos instrumentais que mais se destaca e é amplamente usada para verificar os parâmetros de textura pela versatilidade de analisar uma ampla gama de alimentos sólidos e semissólidos. O resultado dessa análise é um gráfico com uma curva (Figura 11) que apresenta o comportamento específico de cada alimento. É a simulação dos movimentos mecânicos da mordida e mastigação através de curva da força versus o tempo (Neto, 2006). Essa técnica permite o estudo de parâmetros de textura como: Dureza, adesividade, elasticidade, coesividade, gomosidade e mastigabilidade. Sendo que são divididos em propriedades primárias e segundarias:

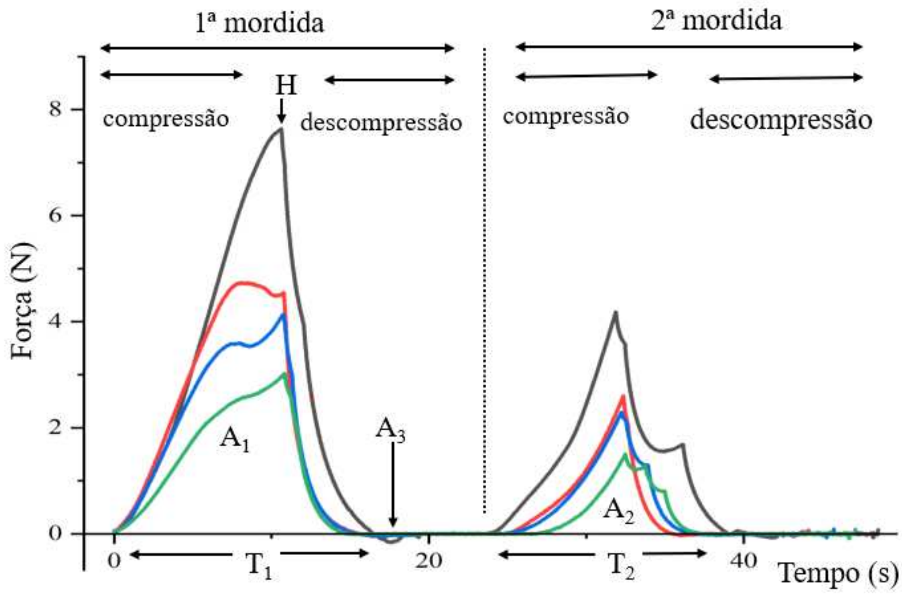
As primárias são:

(a) Dureza: É a força necessário para causar uma deformação;
(b) Adesividade: É a força necessária para remoção da amostra que adere a boca durante a mastigação;
(c) Elasticidade: É a recuperação da amostra ao estado original após compreensão;
(d) Coesividade: Resistencia das ligações internas;

As secundárias são:

(a) Mastigabilidade: É a energia necessário para desintegrar a amostra até o ponto de ser engolido (Produto da dureza, elasticidade e coesividade).
(b) Gomosidade: É a densidade que persiste durante a mastigação (produto da dureza e coesividade).

Figura 11 - Curva padrão das propriedades de textura obtidas por TPA de quatro formulações diferentes de queijo fresco



A saber: H = firmeza; A3= adesividade; A2 /A1= coesividade; T1 /T2= elasticidade; dureza x coesividade = gomosidade; gomosidade x coesividade = mastigabilidade.

Fonte: elaborado pelo autor (2025).

Essa curva apresenta o comportamento de como a amostra se comporta durante o processo realizado para determinar as propriedades de textura e apresenta uma forma mais visual de como analisar os dados obtidos.

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CAPÍTULO 2

-The potential of guabiroba (*Campomanesia xanthocarpa* O. Berg) pulp as a functional ingredient aiming to increase the nutritional dulce de leche properties

Anexo A: Comprovante de submissão artigo "The potential of guabiroba (*Campomanesia xanthocarpa* O. Berg) pulp as a functional ingredient aiming to increase the nutritional dulce de leche properties"

The potential of guabiroba (*Campomanesia xanthocarpa* O. Berg) pulp as a functional ingredient aiming to increase the nutritional dulce de leche properties

O potencial da polpa de guabiroba (*Campomanesia xanthocarpa* O. Berg) como ingrediente funcional visando o aumento das propriedades nutricionais do doce de leite

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ABSTRACT

Dulce de leche is a dairy product made by heat-concentrating milk and sucrose. Dulce de leche could also be made with or without adding other food ingredients, such as fruit pulps. Among the fruit pulps that could be added to dulce de leche is guabiroba. Guabiroba is a nutrient-rich fruit with high antioxidant properties, potential health benefits, and applications in food. Therefore, the objective of the present study was to add the guabiroba pulp (5, 10, 15, 20, 25, and 30%) in dulce de leche. All dulce de leche submitted the following analyses: protein, pH, moisture, total soluble solids, color parameter a*, antioxidant activity, total polyphenols content, and carotenoid content. As the addition of guabiroba pulp increased, it was observed: decrease in protein content (11.43-10.17 g/100g), pH values (6.11-5.68), and total soluble solids content (71.07-59.83 °Brix); in addition to the increase in moisture content (70.92-57.53 g/100g). It added guabiroba pulp-generated dulce de leche samples with a more yellowish color. The dulce de leche samples adding 15 to 30% guabiroba pulp presented an increase in antioxidant activity (283.18-360.38 mg TEAC/100g), total polyphenol content (2,079-2,246 mg GAE/100g), and carotenoid content such as α-carotene (14.30-85.83 μg/100g), β-carotene (32.51-111.51 μg/100g), β-cryptoxanthin (45.48-272.88 μg/100g), and λ-carotene (166.44-998.66 μg/100g). Finally, based on the results obtained, it is possible to verify the potential of guabiroba pulp as a functional ingredient to increase dulce de leche nutritional properties.

Index terms: *Myrtaceae*; functional dairy product; physicochemical composition; antioxidant activity; total polyphenol content.

RESUMO

O doce de leite é um produto lácteo feito pela concentração térmica de leite e sacarose. O doce de leite também pode ser feito com ou sem adição de outros ingredientes alimentares, como polpas de frutas. Entre as polpas de frutas que podem ser adicionadas ao doce de leite está a guabiroba. A guabiroba é uma fruta rica em nutrientes com altas propriedades antioxidantes, potenciais benefícios à saúde e aplicações em alimentos. Portanto, o objetivo do presente estudo foi adicionar a polpa de guabiroba (5, 10, 15, 20, 25 e 30%) no doce de leite. Todos os doces de leite apresentaram as seguintes análises: proteína, pH, umidade, sólidos solúveis totais, parâmetro de cor a*, capacidade antioxidante e teor total de polifenóis. Com o aumento da adição de polpa de guabiroba, observou-se: diminuição do teor de proteína (11,43-10,17 g/100g), dos valores de pH (6,11-5,68) e do teor de sólidos solúveis totais (71,07-59,83 °Brix); além do aumento do teor de umidade (70,92-57,53 g/100g). A adição de polpa de guabiroba gerou amostras de doce de leite com coloração mais amarelada. As amostras de doce de leite contendo 15 a 30% de polpa de guabiroba apresentaram aumento da atividade antioxidante (283,18-360,38 mg TEAC/100g) e dos teores de polifenóis totais (2.079-2.246 mg GAE/100g). Por fim, com base nos resultados obtidos, é possível verificar o potencial da polpa de guabiroba como ingrediente funcional para aumentar as propriedades nutricionais do doce de leite.

Termos para indexação: *Myrtaceae*; produto lácteo funcional; composição físico-química; capacidade antioxidante; teor total de polifenóis.

1 INRODUCTION

Dulce de leche is a dairy product obtained by sugar addition and evaporation. This dairy product has a creamy consistency with a noticeable crystal absence and a brownish-caramel color. The darkest color of dulce de leche is due to the nonenzymatic browning Maillard Reaction. Dulce de leche is an extremely popular confectionary product in South America. The type of ingredients and the process parameters directly affect the product's physicochemical characteristics. Both heat treatment and sugar addition increase the dulce de leche microbiological safety (Silva *et al.*, 2020).

Dulce de leche could be made with or without adding other food ingredients, such as fruit pulps that contain bioactive compounds (Stephani *et al.*, 2019). Bioactive compounds are extra nutritional constituents found in small quantities in foods, including total polyphenols, which have various health benefits, such as antioxidants. Polyphenols, with their broader range of biological activities, have shown potential in preventing chronic diseases, such as diabetes, obesity, and certain types of cancer. Therefore, bioactive compounds, such as total polyphenols, have the potential as functional food ingredients with health benefits. However, bioavailability depends on matrix constituents, concentration, and production process (Sorrenti *et al.*, 2023).

Fruits from the *Myrtaceae* family are known for their high content of bioactive compounds such as total polyphenols and antioxidant activity, including the *Campomanesia xanthocarpa* O. Berg, popularly known as guabiroba (Prestes *et al.*, 2022), an edible yellow-orange fruit with an acid and sweet flavor (Oliveira Raphaelli, de *et al.*, 2021). Oliveira Raphaelli et al. (2021) highlighted the presence of carotenoids in the guabiroba fruit. (Czaikoski *et al.*, 2015) stated that carotenoids are important for health, not only due to their nutritional value as precursors of vitamin A but also because they present a great antioxidant potential. Therefore, guabiroba is a native Brazilian fruit with an important nutritional value and a great economic potential for processing. When introduced into a dietary routine, this fruit is a source of bioactive compounds with high antioxidant activity related to human health benefits. On the other hand, with the addition of guabiroba in the development of new products, it is possible to improve the functionality of the food, encouraging the use of guabiroba in food formulation (Prestes et al., 2022).

Difonzo *et al.*, (2024) reported that the consumers' lifestyle increasingly results from combining a healthy diet with physical activity. Even functional foods have been shown to benefit consumers, making them optimal dietary choices for promoting a healthy lifestyle. Therefore, food companies are also geared toward developing functional products to meet the growing global demand for health-promoting foods. Dairy products are among the most consumed foods in daily life and are a valuable source of proteins (Difonzo et al., 2024). Therefore, this study aimed to determine the potential of guabiroba pulp as a functional ingredient to increase the nutritional properties of dulce de leche. For this reason, a guabiroba pulp was added to a dulce de leche in different amounts (0 - as a control, 5, 10, 15, 20, 25, and 30%). In the sequence, dulce the leche samples were to submit protein, pH, moisture, total soluble solids, color parameter a*, antioxidant activity, total polyphenols content analyses, and carotenoids content.

2 MATERIAL AND METHODS

2.1 GUABIROBA PULP AND DULCE DE LECHE ELABORATION

The guabiroba fruits (*Campomanesia xanthocarpa* O. Berg) were collected in Irati, a municipality in Paraná - Brazil (S25º27'56"; W50º37'51"). It is worth mentioning that they underwent a selection for quality and were subsequently sanitized before starting processing (Braesi DES-20 Pulp Machine, Caxias do Sul, RS, Brazil). After processing, a yield of 31% residue and 69% pulp was obtained (protein 1.4 g/100g, total sugars 7.5 g/100g, and dietary fiber 6.5 g/100g) (Figure 1).

Figure 1 - Harvest fruit for processing, pulper, and packaged pulp.

Namely: A – Fruit harvest; B – fruit selected for processing; C – Fruit pulping process; D – Processed pulp.

Source: Author (2025)

Seven dulce de leche formulations were developed, including one without adding guabiroba pulp as a control. The samples were developed with different percentages of pulp added, being 0 (Control), 5, 10, 15, 20, 25 and 30%. The milk used in the processing was pasteurized whole milk (Tirol ®, Treze Tílias, SC, Brazil) (proteins 3.2 g/100g, total sugars 4.7 g/100g, carbohydrates 4.7 g/100g and calcium 120 g/100g), 20% sucrose (União®, São Paulo, SP, Brazil) and 2% glucose syrup (Yoki®, São Paulo, SP, Brazil). The ingredients were mixed and concentrated to ~ 70 ºBrix (m/m). After the desired concentration, the dulce de leche was cooled to 50 ± 1 ºC (m/m), and the guabiroba pulp was added, packaged, and stored under refrigeration. Dulce de leche samples were elaborated following (Francisquini *et al.*, 2018)

2.2 PHYSICOCHEMICAL ANALYSIS

According to the Instituto Adolfo Lutz manual (IAL, 2008), all samples were evaluated using official standard methods. Triplicates were used for proteins (g/100g), pH, moisture (g/100g), total soluble solids (°Brix), and color parameter a*.

To determine the color parameters of the dulce de leche with guabiroba pulp added, a Minolta Chroma Meter CR-400 colorimeter (Konica Minolta, Osaka, Japan) was used. The colorimeter was adjusted to operate with D65 illuminant and an observation angle of 10°, previously calibrated with a white plate. The CIELab scale was used to measure a* color parameters.

2.3 *IN VIT*RO ASSAYS

The antioxidant capacity via the DPPH (2,2-diphenyl-1-picrylhydrazyl) free radical was determined using the procedure of (Brand-Williams et al., 1995). Then, the absorbance was measured in a Shimadzu-1800 UV/VIS spectrophotometer at 515 nm, with the results expressed as the equivalent antioxidant capacity of Trolox (6-hydroxy-2,5,7,8-tetramethylchroman-2-carboxylic acid) (mg TEAC/100 g). Total polyphenol contents were determined according to the Folin-Ciocalteu assay (Singleton & Rossi, 1965). The absorbance of the samples was measured at 765 nm, and the results were expressed as mg of gallic acid (GAE)/100 g.

2.4 CAROTENOID CONTENT

Carotenoid contents were assessed according to (Rodriguez-Amaya, 2001), with modifications. For carotenoid extraction, 1 g of sample and 20 mL of acetone were weighed in a 50 mL Falcon® tube. After vortex mixing (Biomixer®, Jacareí, São Paulo), the tube containing the mixture was placed in an ultrasound for 30 minutes. The extract was separated with filter paper and a funnel. In a burette, 4 mL of petroleum ether was added, followed by the extracted liquid and 3 mL of type 2 ultrapure water. The burette was left to stand, waiting for the phases to separate. When there was no separation, a few drops of NaOH solution were added, and the separation was done. After separation, the lower fraction (colorless) was removed for disposal, keeping only the colored phase in the burette. The colored phase was removed to a volumetric flask, passing through filter paper with sodium sulfate, retaining any aqueous residue. The burette was cleaned with petroleum ether, avoiding loss of the extract. The carotenoid content was obtained in a UV-Vis spectrophotometer (Shimadzu®, Barueri, SP), using a wavelength of 450 nm for β-carotene, a wavelength of 444 nm for α-carotene, a wavelength of 452 nm for β-cryptoxanthin; and a wavelength of 462 nm for λ-carotene. The carotenoid content was calculated using Equation 1:

$$Carotenoid\ content\ [\mu g/g] = \frac{A\ x\ V\ (dilution)}{A_{1cm}^{1\%}\ x\ sample\ weight}\ x\ 10^6 \quad (1)$$

Where A is Absorbance, V is the total volume of the extract (mL), $A_{1cm}^{1\%}$ is molar absorptivity = 2592 (β-carotene), $A_{1cm}^{1\%}$ (1%) is molar absorptivity = 2800 (α-carotene), $A_{1cm}^{1\%}$ is molar absorptivity = 3100 (λ-carotene) and $A_{1cm}^{1\%}$ is molar absorptivity = 2386 (β-cryptoxanthin).

2.5 STATISTICAL ANALYSIS

The results were expressed as mean±standard deviation. One-way analysis of variance (ANOVA) and Tukey's test were used to determine significant differences ($p < 0.05$) between the results. All statistical analyses were performed using STATISTICA 13.3 software (TIBCO Software Inc., Palo Alto, USA). The steps were performed in triplicate.

3 RESULTS AND DISCUSSION

3.1 PHYSICOCHEMICAL ANALYSIS

The results of the physicochemical analyses are presented in Table 1. All samples showed significant protein values when compared to those established by Brasil (1997) through Ordinance No. 354 and the Brazilian Food Composition Table (TACO, 2011), which established the minimum amount of 5.0 and 5.5 g/100g in dulce de leche, respectively. It is worth mentioning that the values found are above those established, equivalent to a 123% (m/m) increase in protein to the dulce de leche. In the present study, it was possible to identify similar protein contents to those found by (Takeda et al., 2023), who found 10.3 g/100 g in the dulce de leche, denoted as "Ruta del leche." Thus, the results of the analysis of this parameter are promising, given that all samples present high protein content.

For pH values, all formulations showed a decrease compared to the control samples ($p < 0.05$). A decrease in the pH value was observed as the amount of guabiroba pulp added increased. In the literature, it was possible to identify studies whose results were similar to those found. Studies by (Curi et al., 2019) on the composition of jelly with pulp from native Brazilian fruits show a difference ($p < 0.05$) in all their formulations, as well as a decrease in the hydrogen potential. According to (Gaze et al., 2015), the apparent viscosity of dulce de leche decreases at acid pH, and it could change the product's visual aspect.

The moisture content of dulce de leche samples decreased with the increase of guabiroba pulp. Gaze et al. (2015) observed that moisture content in dulce de leche varies among brands, suggesting different operational procedures in dairy factories during processing. Stephani et al. (2019) reported that reducing dulce de leche moisture content allows it to be stored at room temperature, facilitating storage and transportation logistics.

(Leite Júnior & de Castro, 2020) indicate that the ideal total soluble solids (ºBrix) varies between 68 and 70 ºBrix for dulce de leche, and there may be variations depending on the processing. Therefore, it was observed in the present work that the increase in guabiroba pulp content addition in dulce de leche contributed to the decrease in the total soluble solids content.

Adding guabiroba pulp influenced a* color parameter (Table 1). (G. Alves et al., 2020) affirmed that the characteristic color of dulce de leche is due to the presence of melanoidins, the final products of the Maillard Reaction, which can reach concentrations of up to 1.6±0.1 g/100 g. However, dulce de leche is characterized by extensive variability in color parameters, suggesting that different ingredients and procedures used during its processing can influence the color parameters. It was noted in the present study that the guabiroba pulp content influenced the a* parameters. Overall, a* parameter increases when the pulp content used increases. Thus, the parameter a* was higher ($p < 0.05$) for the dulce de leche with a 30% guabiroba pulp than the other formulations elaborated in the present work.

Adding guabiroba pulp in de dulce de leche (5 to 30%) resulted in more yellowish products than without guabiroba pulp (control). However, greater additions of guabiroba pulp resulted in dulce de leche with a more yellowish color.

Tabela 1 - Physicochemical properties of dulce de leche samples with and without adding guabiroba pulp (*Campomanesia xanthocarpa* O. Berg).

	Samples						
	Control	5	10	15	20	25	30
Protein (g/100g)	11.43±0.90[a]	11.160.04[a]	11.02±0.06[a]	9.93±0.50[a]	9.92±0.04[a]	10.55±1.20[a]	10.17±0.20[a]
pH	6.17±0.01[a]	6.11±0.01[b]	6.00±0.01[c]	5.86±0.01[d]	5.80±0.02[d]	5.73±0.01[e]	5.68±0.01[f]
Moisture (g/100g)	70.92±0.30[a]	68.64±0.30[b]	65.54±0.30[c]	63.04±0.20[d]	60.42±0.50[e]	57.53±0.50[f]	58.37±0.20[f]
Total soluble solids (°Brix)	71.07±0.06[a]	68.87±0.06[b]	66.70±0.10[c]	64.10±0.20[d]	63.30±0.10[e]	59.87±0.06[f]	59.83±0.20[f]
Color parameter a*	3.31±0.32[f]	6.13±0.17[e]	7.42±0.92[d]	9.35±0.08[c]	9.55±0.25[c]	10.85±0.03[b]	11.60±0.08[a]

Results are expressed as mean±standard deviation. Different lowercase letters indicate statistical differences between samples ($p < 0.05$) in the same row. The samples were developed with different percentages of pulp added, being 0 (Control), 5, 10, 15, 20, 25 and 30%.

Source: Author (2025)

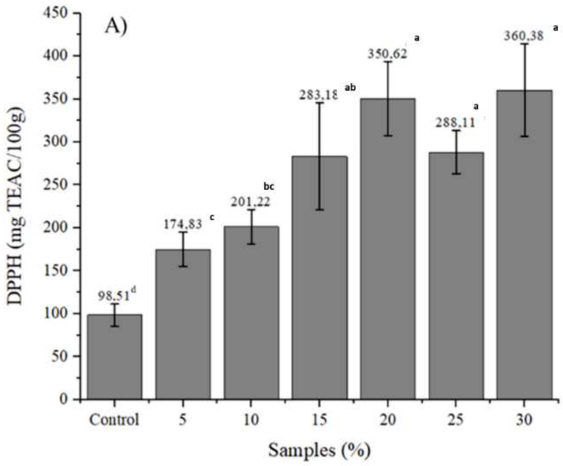
3.2 *IN VITRO* ANTIOXIDANT ACTIVITY

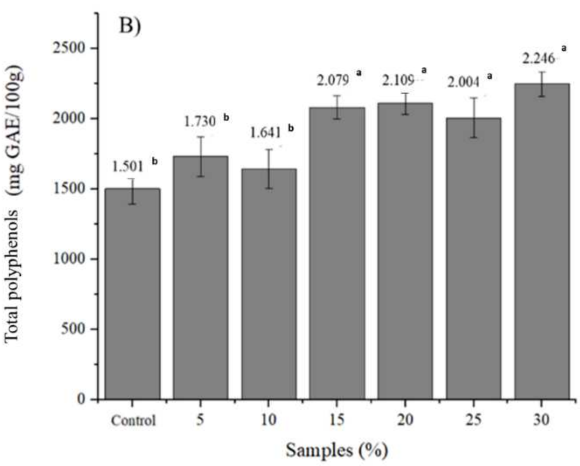
Figure 2A shows the results of the antioxidant activity given by the free radical DPPH (2,2-diphenyl-1-picrylhydrazyl). There were no differences ($p > 0.05$) between the antioxidant activity of dulce de leche samples with 15 to 30% guabiroba pulp. However, all dulce de leche samples elaborated with guabiroba pulp showed greater antioxidant activities than the control sample. (Fardet & Rock, 2018) stated that the antioxidant potential is an important nutritional property of foods, as increased oxidative stress is involved in most diet-related chronic diseases.

(Haminiuk et al., 2012) stated that the high antioxidant activity was expected due to the phytochemical characteristics of the *Myrtaceae* family and the fact that the total polyphenols content present in the matrix analyzed is directly related to its antioxidant activity, emphasizing that with high total polyphenols content, the antioxidant activity will also be higher.

Figure 2B shows the total polyphenol contents in the dulce de leche samples. It is possible to identify the increase of 49.62% (2,246 mg GAE/100g) of the total polyphenol contents in the sample with 30% guabiroba pulp addition when compared with the control (without guabiroba pulp addition) (1,501 mg GAE/100g). These results were similar to those obtained by (de Barros et al., 2023) to dairy products added with cocoa shell extracts (2,210 mg GAE/100g). However, it was also possible to verify that after adding 15% of guabiroba pulp to the dulce de leche, no differences ($p > 0.05$) were observed between the total polyphenol contents of the samples. Concerning total polyphenols, results observed that all dulce de leche samples added with guabiroba pulp could be classified as promising sources of total polyphenols. According to (Vasco et al., 2008), promising sources of total polyphenol contain > 500 mg GAE/100g. (Corrêa et al., 2015) highlighted that total polyphenols exhibit various biological activities, including anti-inflammatory, antimicrobial, and anticancer properties.

Figure 2 - *In vitro* dulce de leche antioxidant activity with adding guabiroba pulp.





Namely: A) DPPH (2,2 diphenyl-1-picrylhydrazyl) results and B) Total polyphenols results. Bars show the standard deviation parameter.

Source: Author (2025)

Results are expressed as mean ± standard deviation. Different letters in the same line indicate statistical differences between samples ($p < 0.05$). Control – Dulce de leche without the addition of guabiroba pulp. 5 – Dulce de leche with a 5% addition of pulp. 10 – Dulce de leche with a 10% addition of pulp. 15 – Dulce de leche with a 15% addition of pulp. 20 – Dulce de leche with 20% addition of pulp. 25 – Dulce de leche with a 25% addition of pulp. 30 – Dulce de leche with a 30% addition of pulp. Total phenolic compounds - results expressed in mg of gallic acid (GAE)/100g and DPPH equivalent to Trolox (mg TEAC/100g).

Table 2 shows the carotenoid levels present in the dulce de leche samples. It was possible to verify that the greater the guabiroba pulp added, the higher the carotenoid content ($p < 0.05$) found in the dulce de leche samples. Among the carotenoids evaluated (α-carotene, β-carotene, β-cryptoxanthin, and λ-carotene), the highest content found was β-carotene, which can be attributed to the whole milk used in the preparation of the dulce de leche. However, except for β-carotene, the other carotenoids were not detected in the dulce de leche samples, that is, without adding guabiroba pulp. Guabiroba pulp contributed to the increase ($p < 0.05$) of α-carotene, β-carotene, β-cryptoxanthin, and λ-carotene in the dulce de leche samples, and this behavior contributed to the improvement of the nutritional value of dulce de leche.(Saini et al., 2015) reported that carotenoids are natural pigments in plants that promote yellow, orange and red coloration in various fruits and vegetables. Guabiroba pulp is one of these orange-colored fruits rich in carotenoids (Saini et al., 2015), which contributed to the increase in the yellowish coloration of dulce de leche with the addition of guabiroba pulp (5 to 30%).

According to Rodriguez-Amaya et al. (2001), carotenoids are phytochemicals that are among the most important constituents of foods, as they are also considered bioactive substances that promote several health benefits.(Pereira et al., 2012) stated that carotenoids also protect biological systems, reacting mainly with the peroxide radical and molecular oxygen. β-carotene is an example of a carotenoid that plays an antioxidant role in lipid phases since it can inactivate reactive chemical species that cause damage to lipoprotein membranes. In addition, some carotenoids, such as β-carotene, can be absorbed and converted into vitamin A by the human body. Vitamin A plays an important role in the human body because it participates in the chemistry of vision, cell differentiation, the immune system, the reproductive and growth system, and the formation of organs and bones (Pereira et al., 2012). Thus, the consumption of elaborated dulce de leche could contribute to the recommended daily intake of carotenoids and vitamin A and reduce the incidence of complications related to their deficiencies.

Tabela 2- Results of carotenoid contents of dulce de leche samples with and without adding guabiroba pulp.

	Sample						
	Control	**5**	**10**	**15**	**20**	**25**	**30**
α-carotene (μg/100g)	< 0.1	14.30±0.02[f]	28.61±0.02[e]	42.46±0.05[d]	57.22±0.05[c]	71.52±0.05[b]	85.83±0.08[a]
β-carotene (μg/100g)	16.72±0.91[g]	32.51±0.90[f]	48.32±1.10[e]	64.12±1.11[d]	79.91±0.87[c]	95.71±1.01[b]	111.51±2.51[a]
β-cryptoxanthin (μg/100g)	< 0.01	45.48±0.52[f]	90.96±0.07[e]	136.44±0.44[d]	181.92±0.65[c]	227.40±0.33[b]	272.88±0.06[a]
λ-carotene (μg/100g)	< 0.01	166.44±1.33[f]	332.88±1.99[e]	499.33±1.43[d]	665.77±2.22[c]	832.215±3.10[b]	998.66±1.89[a]

Results are expressed as mean ± standard deviation. Different letters in the same line indicate statistical differences between samples ($p < 0.05$). Control – Dulce de leche without the addition of guabiroba pulp. 5 – Dulce de leche with a 5% addition of pulp. 10 – Dulce de leche with a 10% addition of pulp. 15 – Dulce de leche with a 15% addition of pulp. 20 – Dulce de leche with 20% addition of pulp. 25 – Dulce de leche with a 25% addition of pulp. 30 – Dulce de leche with a 30% addition of pulp. Different letters in the same line indicate statistical differences between samples ($p < 0.05$).

Source: Author (2025)

4 CONCLUSIONS

All the dulce de leche samples (control up to 30% guabiroba pulp) showed a decrease in the protein contents and a decrease in pH value as the guabiroba pulp content increased. The higher guabiroba pulp content contributed to obtaining dulce de leche with higher moisture and lower total soluble solids. The guabiroba pulp contributed to the increase in the yellowish color of dulce de leche samples. All dulce de leche samples showed high antioxidant activity and total polyphenol contents. However, the dulce de leche samples containing 15 to 30% guabiroba pulp showed a significant increase in antioxidant activity, total polyphenol contents, and carotenoid content (α-carotene, β-carotene, β-cryptoxanthin, and λ-carotene). Finally, it can be concluded that considering only the physicochemical parameters, all the samples could be produced. Samples in which 15 to 30% of guabiroba pulp were used are recommended for antioxidant activity and total polyphenol contents.

Author contribution

Conceptual idea: Mindelo, L.J.O.; Prudencio, E.S.; .Methodology design: Mindelo, L.J.O.; Andrade, D.R.M.; Helm, C.V.; Prudencio, E.S.; Data collection: Mindelo, L.J.O.; Prestes, A.A.; Andrade, D.R.M.; Fiebig, M.S.; Carvalho, A.C.F.; Helm, C.V.; Prudencio, E.S.; Data analysis and interpretation: Mindelo, L.J.O.; Prestes, A.A.; Andrade, D.R.M.; Fiebig, M.S.; Carvalho, A.C.F.; Helm, C.V.; Prudencio, E.S.; and Writing and editing: Mindelo, L.J.O.; Prestes, A.A.; Prudencio, E.S.

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CAPÍTULO 3

The potential of guabiroba pulp application and its effects aiming at the elaboration of functional fresh cheeses

Anexo B: Comprovante de submissão artigo "The potential of guabiroba pulp application and its effects aiming at the elaboration of functional fresh cheeses"

The potential of guabiroba pulp application and its effects aiming at the elaboration of functional fresh cheeses

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ABSTRACT

Fresh cheeses are dairy products that consumers consider highly acceptable, even more so when functional properties are added to them. This study aimed to add guabiroba pulp (5, 10, 15%) in fresh cheeses. This way, fresh cheeses were characterized by their physical-chemical properties, color, texture, total phenolic compounds, *in vitro* antioxidant activity, sugars, hydrophilic and lipophilic compounds, multi-element profile, and antimicrobial activity. Adding guabiroba pulp decreased water activity, ash content, and pH value. The guabiroba pulp also reduced the lightness of the fresh cheeses, and its addition resulted in cheeses with a hue visible to the naked eye, tending towards yellow-reddish. Guabiroba pulp addition decreased firmness, elasticity, and gumminess. It was evident that using guabiroba pulp increased the total content of phenolic compounds, the *in vitro* antioxidant activity, and the carotenoid content. All fresh cheese was represented by lactose, galactose, glucose, sucrose, and fructose. The hydrophilic compounds acquired as important components with high expression in the fresh cheese samples with adding guabiroba pulp were organic acids > cyclitol > amino acids > sugar acid. In contrast, the lipophilic compound was the fatty acid class. The multi-element profile of fresh cheeses was represented by Ca > P > S > K > Mg > Zn > Sr. In contrast, toxic minerals were not detected in the cheese samples. Antimicrobial activity against *Staphylococcus aureus* and *Escherichia coli* was observed for fresh cheese samples with guabiroba pulp addition. In the present study, guabiroba pulp content is recommended to be between 10- 15%.

Keywords: *Campomanesia xanthocarpa* O. Berg. Bioactive compounds. Functional food. Dairy product. Innovative food.

1 . INTRODUCTION

Cheese is one of the most popular dairy products consumed worldwide and has a high commercial value (Christaki *et al.,* 2021). Fresh cheese shows excellent yield, is easily elaborated, and has low cost (Silva *et al*., 2024). Consumers' wide acceptance of dairy products, such as cheese, has instigated the dairy industry to add value-added compounds to dairy products. Muñoz-Bas *et al*. (2024) reported that cheese had been an excellent matrix for incorporating these value-added ingredients obtained from fruit, improving their nutritional, functional, and technological properties. In this case, their application in cheese has enhanced the profile of bioactive compounds and boosted their antioxidant properties (Muñoz-Bas *et al*., 2024). As cited by Amorim *et al*. (2024), these bioactive compounds offer a range of health benefits due to their antioxidant, antimicrobial, and anti-inflammatory properties, which in turn are associated with controlling the development and progression of most chronic diseases, such as obesity, diabetes, cardiovascular diseases, neurodegenerative disorders, and cancer.

With a high content of bioactive compounds and antioxidant activity, fruits of the *Myrtaceae* family, such as *Campomanesia xanthocarpa* O. Berg, popularly known as guabiroba, are considered functional fruits (Almeida *et al*., 2011). Guabiroba is a fruit species commonly found in the forests of the South, Southeast, and Central-West of Brazil, where the Cerrado biome predominates. It can also be found in Argentina and Uruguay (Silva & Kempka, 2023).

Guabiroba, a Brazilian fruit, stands out for its bioactive compound content, polyphenols, and carotenoids. Thus, the phytochemicals of guabiroba are elucidated regarding its high antioxidant activity, which is related to benefits to human health when introduced into a dietary routine (Prestes *et al*., 2022). These properties of guabiroba make its pulp suitable for consumption *in natura* or food compositions; however, guabiroba pulp is not yet an ingredient used on a large commercial scale. Amorim *et al*. (2024) reported that fruits and pulps belonging to Brazilian biodiversity are still little explored as ingredients by the food industry, presenting enormous potential for research and development of new products.

A source of bioactive compounds, guabiroba pulp was evaluated as a functional additive in fermented milk by Prestes et al. (2021) and in petit suisse cheese by Messias et al. (2021). Prestes et al. (2023) also used guabiroba pulp in a fermented milk beverage obtained from freeze concentrated whey. Based on these results, fresh cheese could also serve as an interesting matrix to incorporate guabiroba pulp.

Fresh cheeses have a high moisture content, which makes the matrix more porous and capable of easily absorbing bioactive compounds. Thus, due to their structure, fresh cheeses can be formulated to incorporate several bioactive compounds, such as antioxidants, polyphenols, and carotenoids. In addition, cheese proteins, such as casein and lipids, would be excellent vehicles for the controlled release of bioactive compounds (Muñoz-Bas et al., 2024). Finally, bioactive compounds can be effectively preserved in fresh cheeses since the production process usually involves lower temperatures than ripened cheeses, which could minimize the thermal degradation of temperature-sensitive substances, such as certain bioactive compounds.

From an innovation perspective for fresh cheese, this study aimed to develop a new functional cheese from the addition of a Brazilian native fruit rich in bioactive compounds, contributing to the use of alternative sources to conventional functional raw materials. This study objective was to characterize innovative fresh cheeses added with guabiroba pulp concerning physicochemical, color properties, texture properties, total phenolic compounds, *in vitro* antioxidant activity, carotenoid content, sugar analysis, hydrophilic and lipophilic compounds determination, multi-element profile, and antimicrobial activity.

2 MATERIALS AND METHOD

2.1 MATERIALS

Guabiroba fruits (*Campomanesia xanthocarpa O. Berg*) were collected in Irati (Paraná State, Brazil) (S25º27'56"; W50º37'51"). The fruits were selected, sanitized, and subsequently processed in a pulp machine (model DES-20, Braesi, Caxias do Sul, RS, Brazil) to obtain the pulp, yielding 31% residue and 69% guabiroba pulp. The composition of the pulp was 1.4 g of protein/100g, 7.5 g of total sugars/100g, and 6.5 g of dietary fiber/100g. The milk used in processing was pasteurized whole milk (Tirol®, Treze Tílias, SC, Brazil), with a composition of 3.2 g of protein/100g, 4.5 g of total sugars/100g, and 4.7 g of carbohydrates/100g,

2.2 SAMPLES PREPARATION

Four formulations of cheese added with guabiroba pulp were developed, with different addition percentages. The control sample had no addition, while the others contained 5%, 10%, and 15% of guabiroba pulp (Fig.1), denoted as sample 0, sample 5, sample 10, and sample 15, respectively.

Figure 1 - Fresh cheese formulations added with guabiroba pulp, where 0 = control sample (without guabiroba pulp); 5 = sample with 5% guabiroba pulp; 10 = sample with 10% guabiroba pulp; 15 = sample with 15% guabiroba pulp

Source: Author (2025).

2.3 PHYSICOCHEMICAL ANALYSIS

The fresh cheese samples' titratable acidity, pH, moisture, protein, and ash contents were determined according to the Analytical Standards Manual of Institute Adolfo Lutz (2008). Titrable acidity was expressed in lactic acid g acid lactic per 100 g. The pH was measured using a digital pH meter (Kasvi®, São Paulo, SP, Brazil), calibrated with pH 4.0 and 7.0 buffer solutions, under ambient temperature conditions (Tecnaltec-7®, São Paulo, SP, Brazil). Moisture content (g/100g) was evaluated by drying in a forced-air oven (TECNAL®, Piracicaba, SP, Brazil) at 105 ± 1 °C until constant weight. The protein content (g/100g) was quantified using the Kjeldahl method (TECNAL® equipment, Piracicaba, SP, Brazil) by measuring the total nitrogen content multiplied by factor 6.8. The water activity (Aw) was measured instrumentally using the AquaLab meter equipment (Model CX-2, Decagon Devices, Pullman, WA, USA).

The color analyses of the fresh cheese samples were determined using a colorimeter Minolta Chroma Meter CR-400 (Konica Minolta, Osaka, Japan), adjusted to operate with D65 lightning and 10° of observation angle. The colorimeter was calibrated with a white standard plate, and the CIELab color scale was used to measure the L*, a*, and b* parameters. The L* parameter ranges from 0 to 100, indicating luminosity (variation from black to white). The b* axis is the variation from yellow (+b*) to blue (-b*), and the a* axis shows the variation from red (+a*) to green (-a*). The total difference of color (ΔE*) between the measured values of each fresh cheese (5, 10, 15% of guabiroba pulp) with the control sample (cheese without guabiroba pulp), as expressed in Eq. 2.

$$\Delta E^* = \sqrt{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2} \quad (1)$$

Where ΔL* is the difference in luminosity, Δa* represents the intensity of the red color, and Δb* is the intensity of the yellow color for each fresh cheese sample. It was realized in six measurements.

2.4 TEXTURE ANALYSIS

A texturometer model TA-XT plus was used for the texture analysis of the samples (Stable Micro Systems, Texture Exponent software, Surrey, UK). An aluminum probe of 25 mm diameter was used to compress the fresh cheese samples (50 mm diameter and 20 mm height). The measurements were made at 5 ± 1 °C, with a test speed of 1.0 mm/s and distance of 10.0 mm, according to the methodology described by Buriti et al. (2005). The data for force as a function of time were obtained for the two compression-decompression cycles using the TA-XT plus software. The following parameters were obtained: firmness (N), elasticity (Ns), cohesiveness, and gumminess (N).

2.5 TOTAL PHENOLIC COMPOUNDS AND IN VITRO ANTIOXIDANT CAPACITY

An amount of 0.5 g of the sample was weighed into a plastic centrifuge tube with a screw cap, to which 50 mL of boiling water was added. The tube was subjected to ultrasound (Biovera®, Rio de Janeiro, RJ, Brazil) for 30 min. After extraction, the solution was filtered through fast filtration paper into a 100 mL volumetric flask, and the volume was completed with distilled water. Total phenolic compounds (TPC) were determined using a colorimetric analysis with the Folin-Ciocalteau reagent, according to Singleton and Rossi (1965) and Gan et al. (2013) protocols, with adaptations. The reaction occurred in the dark, at room temperature, for 90 minutes, and absorbance was measured at 725 nm using a Shimadzu-1800 UV–VIS® spectrophotometer (Kyoto, Japan). The results were expressed as gallic acid equivalents (GAE) micrograms per 100 grams of dry sample (µg GAE/100g). The gallic acid calibration curve was constructed with concentrations ranging from 0 to 100 mg/L.

The antioxidant capacity was determined through the DPPH free radical method (2,2-diphenyl-1-picrylhydrazyl), following the procedure of Brand-Williams et al. (1995). The reaction was conducted in the dark, at room temperature, for 30 min. The absorbance was measured using a UV/VIS spectrophotometer (Shimadzu, Kyoto, Japan) at 515 nm, with results expressed as microgram of Trolox equivalent antioxidant capacity (TEAC) per 100 grams (µg TEAC/100g).

The ABTS+ (2,2-casino-bis acid (3-ethylbenzothiazolin-6-sulfonic acid) radical inhibition activity was performed according to Re et al. (1999), using a UV/VIS spectrophotometer (Shimadzu, Kyoto, Japan) at 734 nm. The results were expressed as micrograms of Trolox equivalent antioxidant capacity (TEAC) per 100 grams (µg TEAC/100g).

2.6 CAROTENOID CONTENT

Carotenoid content was analyzed according to Rodriguez-Amaya (2001) with modifications. For carotenoid extraction, 1 g of sample was weighed, and 20 mL of acetone was added into a Falcon® 50 mL tube. After vortex mixing (Biomixer®, Jacareí, São Paulo), the tube with the mixture was subjected to ultrasound for 30 minutes. The extract was filtered using filter paper and a funnel. In a burette, 4 mL of petroleum ether was added, followed by the extract and 3 mL of ultrapure type 2 water. The burette was then left to stand until phase separation occurred. If separation did not happen, a few drops of NaOH solution were added, waiting for phase division. The lower, colorless phase was discarded, while the colored phase was kept in the burette. This colored phase was transferred to a volumetric flask, passing through a filter with sodium sulfate to eliminate any aqueous residue. The burette was washed with petroleum ether to avoid extract loss. Carotenoid levels were measured using a UV-Vis spectrophotometer (Shimadzu®, Barueri, SP), with the following wavelengths: 450 nm for β-carotene, 444 nm for α-carotene, 452 nm for β-cryptoxanthin, and 462 nm for λ-carotene. The carotenoid content was calculated using Eq. (2).

$$\text{Carotenoid content } (\mu g/g) = \frac{\text{A}\times\text{VmL (Dilution)}}{\text{A } 1\%\ x\ Sample\ weight} \text{x}10^6 \quad (2)$$

Where A is absorbance, V is the total extract volume (mL), and A1% is the molar absorptivity: 2592 for β-carotene, 2800 for α-carotene, 3100 for λ-carotene, and 2386 for β-cryptoxanthin.

2.7 SUGAR ANALYSIS

An ICS 3000 Ionic Chromatograph Dionex (San Donato Milanese, Italy) conducted chromatographic analyses of lactose, galactose, sucrose, glucose, and fructose. The chromatographic separation was performed with a CarboPac PA20 column (3 mm × 150 mm, Dionex) equipped with a guard column (CarboPac PA20, 3 mm × 30 mm, Dionex) according to the methodology proposed by Neri et al. (2011), with some modifications. The following work condition was used: NaOH 5.0×10^{-2} mol/L as mobile phase, a flow rate of 0.5 mL/min, a 35 min run at a column temperature of 30 ± 1 °C, and a volume of injection of 10 µL. As the Dionex technical manual recommended, sugar detection was performed using the time/potential waveform A. Sugar identification and quantification were performed using retention times. The related sugar calibration curve was performed.

2.8 GAS CHROMATOGRAPHY-MASS SPECTROMETRY (GC–MS) ANALYSIS

The gas chromatography-mass spectrometry (GC-MS) analysis (Agilent®, Santa Clara, CA, USA) was determined in the fresh cheeses with guabiroba pulp addition (5, 10, 15%). According to Lima et al. (2020), the sample extraction processes were first realized. After these processes, the samples containing the hydrophilic and lipophilic compounds were analyzed using gas chromatography coupled to an ion trap mass spectrometer in split mode (1:25). The samples were submitted to DB-5 column (30 m × 0.25 mm × 0.25 µm) at a temperature of 250 ± 1ºC, using Helium gas at 1.5 mL/min for transportation. The GC oven was set at 70 ± 1°C, 1 min isotherm, and heating to 320 ± 1ºC at a rate of 8 °C/min, with a final 5 minutes isotherm. The mass spectrometer was operated in positive mode with electron impact ionization at 70 eV and ion source temperature at 200 ± 1°C. The compounds were identified through the AMDIS® *software* using the Golm Metabolome Database reference collection (Hummel et al., 2010) for hydrophilic compounds, and a library was built in the AMDIS *software* with samples analyzed for lipophilic compounds.

2.9 MULTI-ELEMENT PROFILE

Multi-element profile measurements were performed using an inductively coupled plasma optical emission spectrometer (ICP-OES) (model iCAP 6000®, Thermo Analytical, USA). The analytes and respective monitored wavelengths were: Al (308.215 nm), As (189.042 nm), Ca (422.673 nm), Cd (228.802 nm), Co (228.616 nm), Cr (283.563 nm), Cu (324.754 nm), Fe (238.204 nm), K (769.886 nm), Mg (279.553 nm), Mn (257.610 nm), Na (589.592 nm), P (214.914 nm), Pb (220.353 nm), S (182.034 nm), Se (196.090 nm), Sr (407.771 nm), and Zn (213.856 nm). The ICP-OES had a Miramist nebulizer (Burgener Research®, Mississauga, Ontario, Canada) and a cyclonic spray chamber. Operational parameters included radial vision, a pump rate of 50 rpm, a plasma gas flow of 12 L/min, radio frequency power of 1150 W, and an auxiliary gas flow rate of 1.0 L/min. Argon was the main and auxiliary gas with a minimum purity of 99.95% (Air Liquide, Rio de Janeiro, RJ, Brazil). Calibration curves were prepared for the analytes with concentrations ranging from 0.05 to 2.5 mg/L for Al, As, Cd, Co, Cr, Cu, Fe, Mg, Mn, Pb, Se, Sr, and Zn, and from 0.5 to 20 mg/L for Ca, K, Na, P, and S.

Sample preparation was conducted according to the methods described by Melo et al. (2024). In each experiment, 0.570 g of cheese sample was weighed directly into Teflon® microwave vessels (Microwave Model Reaction System/Multiwave PRO®, Anton Paar, Graz, Austria). Subsequently, 1.58 mL of 14 mol/L HNO_3 and 1.42 mL of ultrapure water were added. The vessels were sealed and subjected to the following temperature program: heating to 200 ± 1 °C for 8 minutes, holding at 200 ± 1 °C for 14 minutes, and cooling to 65 ± 1 °C for 23 minutes. The samples were then transferred to 50.0 mL polyethylene flasks, and ultrapure water was added up to 30 mL. Individual standard solutions with a concentration of 1,000 mg/L of the analytes were used for the calibration curves.

2.10ANTIMICROBIAL ACTIVITY

An amount of 3.0 ± 0.2 g of each fresh cheese sample (without – control and with 5, 10, and 15% guabiroba pulp) was weighed and stored in Falcon® tubes, then homogenized with 3 mL of sterile distilled water with constant vortex agitation (Biomixer®, Jacareí, São Paulo) for 5 minutes. The homogenized samples were filtered through filter paper and then filtered again through 0.22 µm thick filters to sterilize each extract. The pathogenic microorganism strains used were *Staphylococcus aureus* ATCC 25923 and *Escherichia coli* ATCC 25922 to screen for activity against gram-positive and gram-negative microorganisms. Broth microdilution assay was performed using incubation time and inoculum concentration parameters, according to De Bona et al. (2014). Standardized inocula on the McFarland scale 0.5 ($1x10^8$ to $2x10^8$ colonies forming unit, CFU/mL) using brain heart infusion broth (BHI) were prepared and reduced to an approximate concentration of $1x10^3$ to $2x10^3$ CFU/mL by serial dilution. One hundred microliters of the inoculum were added to a sterile microtube, and 100 µL of each extract was previously produced using fresh cheese samples. A control using only 100 µL of the inoculum and 100 µL of BHI was performed. Microtubes containing $1x10^3$ to $2x10^3$ CFU/mL were incubated for 6 h in a shaker-type incubator with 200 rpm rotation at 37 ± 1 ºC. After incubation, the inocula in contact with the extract was diluted in sterile saline and plated on nutrient agar for colony counting. For microtubes containing 1 g of the sample plus the inoculum, plating was performed on Baird-Parker agar selective medium for *S. aureus* and Tryptone Bile Glucuronide (TBX) agar selective medium for *E. coli*. The results were expressed as a percentage of reduction (%) of *S. aureus* and *E. coli* (Eq. 3).

$$\text{Reduction (\%)} = 100 \text{ x } \frac{(GLPCC - GLPCS)}{GLPCC} \tag{3}$$

GLPCC is the growth log of a pathogen in the control cheese, and GLPCS is the growth log of a pathogen in the cheese sample (with 5, 10, or 15% guabiroba pulp).

2.11STATISTICAL ANALYSIS

Samples were analyzed in triplicate, with three independent measurements performed for each. Data analysis was conducted using STATISTICA 13.3 *software* (TIBCO® Software Inc., Palo Alto, USA). Results are presented as mean ± standard deviation. The significant differences ($p < 0.05$), analysis of variance (ANOVA), and Tukey's HSD test with a 95% confidence level were applied.

3 RESULTS AND DISCUSSION

3.1 CHEMICAL AND PHYSICAL ANALYSIS

Table 1 presents the physicochemical and colorimetric parameters of the fresh cheese samples without (Sample 0, control) and with guabiroba pulp (5, 10, 15%). From these results, it was possible to verify that the progressive increase in the guabiroba pulp content in the fresh cheese samples resulted in a decrease ($p < 0.05$) in the Aw values. Another decrease ($p < 0.05$) was verified for the pH value of the fresh cheese sample added with 15% guabiroba pulp. On the other hand, guabiroba pulp (5, 10, 15%) contributed to the increase ($p < 0.05$) in the ash content of the fresh cheese samples. However, the addition of guabiroba pulp (5, 10, 15%) practically did not influence ($p > 0.05$) the protein, moisture, and titratable acidity contents in modified fresh cheeses. The parameters L*, a*, and b* are part of the CIE Lab* color space, a colorimetric system that describes all perceptible colors. Regarding the L* parameter, it was observed that adding guabiroba pulp contributed to the decrease ($p < 0.05$) of the lightness values of the fresh cheese samples by increasing the guabiroba pulp. Thus, the increase in the guabiroba pulp content resulted in fresh cheeses with a tendency towards a yellow-reddish hue. As expected, the orange hue of the guabiroba increases these values. Tura et al. (2024) stated that yellow cheeses are preferred by consumers, while El-Loly et al. (2024) highlighted that the yellow-reddish color is attributed to the addition of fruits in rich cheeses with a more attractive and appetizing appearance, which can enhance the overall taste of the cheese. Therefore, the increase in the color parameters a* and b* can be explained by the high content of carotenoids normally found in guabiroba pulp (Lima et al., 2023). Regarding the ΔE* parameter, it was possible to note that as the content of guabiroba pulp in the cheeses increased, the values for the color difference between the sample and the control were higher. According to Quintanilla et al. (2019), ΔE* values between 1 and 3 are not perceptible to the human eye, while values above 3 are visible. Therefore, all fresh cheese samples had values greater than 3 for the color difference, indicating that the increased addition of guabiroba pulp (5, 10, 15%) resulted in greater visualization of the color difference. As previously mentioned, this behavior was also due to carotenoids in the guabiroba pulp.

Tabela 1 - Physicochemical, texture and colorimetric parameters of fresh cheese formulation samples added with guabiroba pulp.

	Samples			
	0	5	10	15
Physicochemical parameters				
Protein (g/100g)	20.18±0.70^{a}	20.00± 0.70^{a}	19.84 ± 0.40^{a}	20.94± 1.60^{a}
Moisture (g/100g)	41.81±0.70^{ab}	40.77± 0.45^{b}	40.77 ± 0.10^{b}	42.69± 0.30^{a}
Titratable acidity (g lactic acid/100g)	2.03±0.70^{a}	1.98 ± 0.10^{a}	1.98 ± 0.03^{a}	1.99 ± 0.03^{a}
Aw	0.886±0.002^{a}	0.875±0.002^{b}	0.864±0.004^{c}	0.865±0.019^{c}
pH	5.83 ± 0.02^{a}	5.84 ± 0.03^{a}	5.87 ± 0.05^{a}	5.76 ± 0.02^{b}
Ash (g/100g)	2.94 ± 0.04^{b}	3.91 ± 0.53^{a}	3.50 ± 0.10^{a}	3.38 ± 0.06^{a}
Colorimetric parameters				
L*	89.99±0.50^{a}	81.00± 0.80^{b}	78.31 ± 0.30^{c}	77.51± 1.60^{c}
a*	4.21 ± 0.20^{d}	9.71 ± 0.10^{c}	11.83 ± 0.10^{b}	15.35± 0.30^{a}
b*	23.62±0.40^{d}	38.34± 0.40^{c}	44.04 ± 0.30^{b}	54.00± 1.10^{a}
ΔE*	*	17.74± 0.50^{c}	24.74 ± 0.10^{b}	34.69± 1.30^{a}
Texture parameters				
Firmness (N)	7.94±0.90^{a}	4.92 ± 0.11^{b}	3.29 ± 0.20^{c}	3.18 ± 0.30^{c}
Elasticity (N s)	75.80± 0.19^{a}	67.84± 0.17^{b}	66.60 ± 0.41^{b}	49.70± 0.30^{c}
Cohesiveness	0.46 ± 0.06^{a}	0.28 ± 0.04^{b}	0.30 ± 0.20^{b}	0.27 ± 0.02^{b}
Gumminess (N)	3.65 ± 0.15^{a}	1.37 ± 0.24^{b}	1.02 ± 0.01^{c}	0.89 ± 0.14^{c}

Sample 0 is the control sample (without guabiroba pulp); Sample 5 is the sample with 5% guabiroba pulp; Sample 10 is the sample with 10% guabiroba pulp; and Sample 15 is the sample with 15% guabiroba pulp. L*: represents lightness, ranging from 0 (black) to 100 (white). a*: represents the red color tone. b*: represents the yellow tone. ΔE*: represents the total difference of color between the measured values of each fresh cheese (5, 10, 15% of guabiroba pulp addition) with the control sample. Results are expressed as mean ± standard deviation (n = 3). [a-c] Within a row, different lowercase letters indicate significant differences between samples ($p < 0.05$).

Source: Author (2025)

Table 1 also presents the results of the texture parameters of the modified fresh cheeses with and without the addition of guabiroba pulp (5, 10, 15%). Compared to the control cheese, it was observed that the firmness, elasticity, cohesiveness, and gumminess of the fresh cheese samples decreased with the addition of guabiroba pulp. The same behavior was found by El-Loly et al. (2024) for processed cheese using papaya pulp. These authors attributed this behavior to the more marked hydration and the consequent weakness in the casein network due to the presence of fruit pulp. The texture parameters of firmness, elasticity, cohesiveness, and gumminess decreased ($p < 0.05$) with adding guabiroba pulp. Among the samples of fresh cheeses increased with guabiroba pulp, there was a decrease ($p < 0.05$) in the parameters of firmness and gumminess when 10% pulp was added. At the same time, elasticity decreased ($p < 0.05$) with the use of 15% pulp. Hueso et al. (2023) reported that different conditions of the cheese manufacturing process impacted the gel's firmness. As was selected in the cheeses with 10% guabiroba pulp, Costa et al. (2015) emphasized that changes in the composition of proteins present in foods can affect the firmness of a product. Ali et al. (2022) reported that the firmness and gumminess of cheeses are closely related. As reported by these authors, the relationship between firmness and gumminess was also verified in the present study.

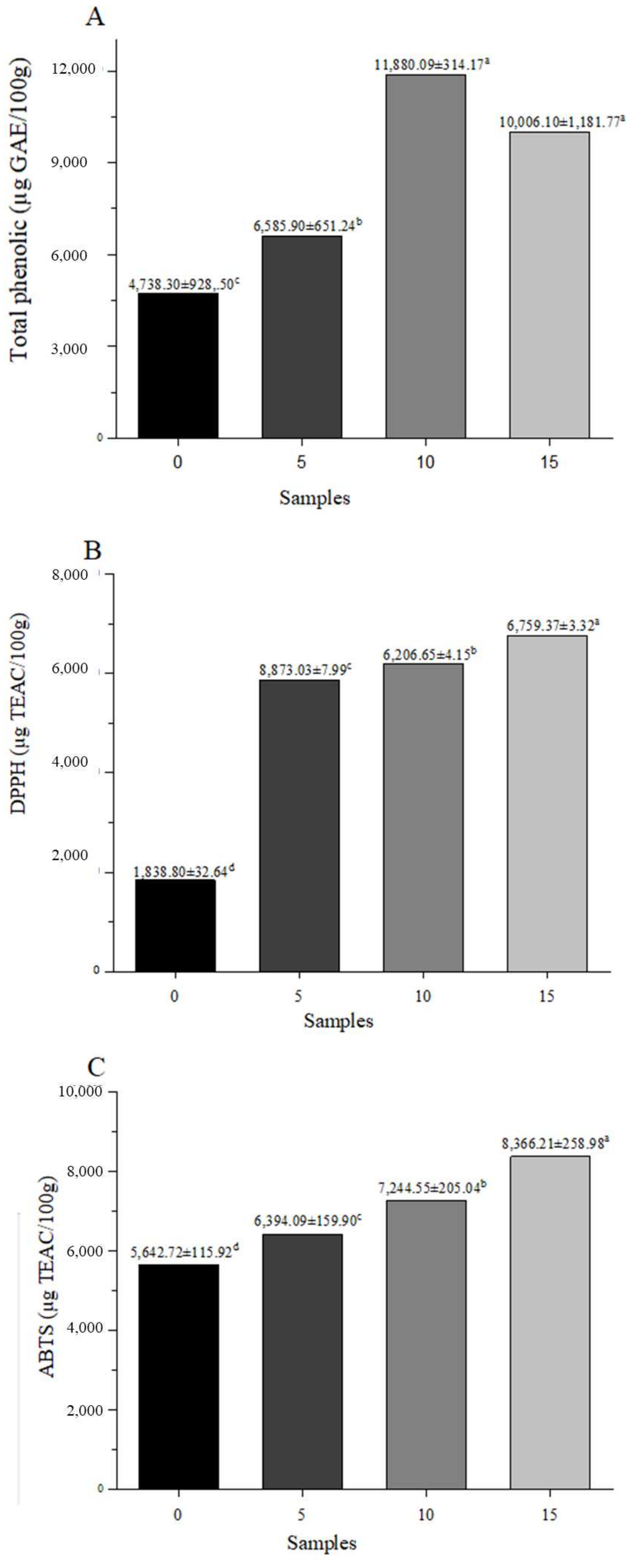
According to Krentz et al. (2022), elasticity is the speed at which a product returns to its deformed state once the acting force is removed. According to this research, the elasticity parameter was lower in the sample 15 (with 15% guabiroba pulp). The decrease in elasticity may also be due to a change in the casein network. Acevedo-Correa et al. (2025) found that adding sesame protein isolates generated new interactions between sesame protein and casein colloids, which may affect the elasticity parameter.

The amounts of guabiroba pulp used in this study (5, 10, 15%) were not able to influence the cohesiveness parameter ($p > 0.05$); however, as previously mentioned, it was lower ($p < 0.05$) than sample 0 (without the addition of guabiroba pulp). Cohesiveness would be how much food can be deformed before rupture. Thus, it was observed that the guabiroba pulp components used did not influence this textural parameter. Jiang et al. (2023) stated that cohesiveness represents how much the material will be compressed between the teeth before breaking; the more cohesive the material is, the more the material will maintain the same shape.

3.2 TOTAL PHENOLIC COMPOUNDS AND IN VITRO ANTIOXIDANT CAPACITY

The total phenolic compound results are shown in Figure 2 A. It was possible to note that adding guabiroba pulp increased ($p < 0.05$) the total phenolic compound content of the fresh cheese samples by 1.4 to 2.5 times. This result is in agreement with that reported by Salehi (2021), which states that dairy products with the addition of some bioactive compounds are a very promising line of research for the dairy industry when the objective is to increase functionality. However, comparing the values obtained for all the samples evaluated, it was possible to verify that the increase in total phenolic compound content was greater than ($p < 0.05$) the cheese samples with guabiroba pulp addition but did not differ ($p > 0.05$) between the fresh cheeses containing 10 and 15% of guabiroba pulp. Thus, after adding ≥ 10% guabiroba pulp to fresh cheeses, no differences ($p > 0.05$) were found between the total phenolic compound contents of the cheese and the fresh cheeses. These results were confirmed by those reported by Salehi (2021), Feiden et al. (2025), and Hernández et al. (2025), who highlight the development of functional cheeses with the addition, for example, of some fruit pulp when the subject is improving functionality. The total phenolic compounds of guabiroba (*Campomanesia xanthocarpa*) offer several health benefits, mainly due to their antioxidant, antidiabetic, anti-inflammatory, and hypotensive properties (Prestes et al., 2022). On the other hand, Prestes et al. (2022) reported that adding guabiroba to develop new products can reduce the use of chemical additives. Guabiroba fruit is rich in phenolic compounds, which have high antioxidant potential. Antioxidants have attracted considerable attention as potential compounds to prevent or delay oxidative stress-related diseases (Raphaelli et al., 2021).

Figure 21 - Results from (A) total phenolic compounds and *in vitro* antioxidant capacity by the (B**)** DPPH free radical method (2,2-diphenyl-1-picrylhydrazyl) and (C) ABTS+ (2,2-casino-bis acid (3-ethylbenzothiazolin-6-sulfonic acid) radical inhibition activity**.**


A
Total phenolic (µg GAE/100g)
12,000
9,000
6,000
3,000
0
4,738.30±928,.50c
6,585.90±651.24b
11,880.09±314.17a
10,006.10±1,181.77a
0
5
10
15
Samples
B
DPPH (µg TEAC/100g)
8,000
6,000
4,000
2,000
0
1,838.80±32.64d
8,873.03±7.99c
6,206.65±4.15b
6,759.37±3.32a
0
5
10
15
Samples
C
ABTS (µg TEAC/100g)
10,000
8,000
6,000
4,000
2,000
0
5,642.72±115.92d
6,394.09±159.90c
7,244.55±205.04b
8,366.21±258.98a
0
5
10
15
Samples

Sample 0 is the control sample (without guabiroba pulp); Sample 5 is the sample with 5% guabiroba pulp; Sample 10 is the sample with 10% guabiroba pulp; and Sample 15 is the sample with 15% guabiroba pulp. Results are expressed as mean ± standard deviation (n = 3). [a-c] Different lowercase letters indicate significant differences between samples ($p < 0.05$).

Source: Author (2025).

Regarding the *in vitro* antioxidant capacity, Figures 2B and 2C show the results of the control of the fresh cheese sample by adding guabiroba pulp (5, 10, 15%). The increase in antioxidant activity attributed to the guabiroba pulp added to the fresh cheeses was estimated using the DDPH and ABTS methods. By the DPPH method, it was observed that the fresh cheese samples containing 5, 10, and 15% of guabiroba pulp presented a gradual increase ($p < 0.05$) of 220, 238, and 268% in antioxidant activity when compared to the control sample (without the addition of guabiroba pulp), respectively. A similar behavior was also selected through the ABTS method, whose increase ($p < 0.05$) in antioxidant activity for fresh cheese samples added with 5, 10, and 15% of guabiroba pulp were 13, 28, and 48%, when compared to the control sample, respectively. These results corroborate those obtained by Prestes et al. (2021) and Prestes et al. (2024). Both authors observed that adding guabiroba, a fruit known for its bioactive compounds, to dairy products such as yogurt and fermented milk increases their antioxidant activity. However, the value of the increase in antioxidant activity found in the present study, compared to those obtained by Prestes et al. (2021) and Prestes et al. (2024) for fermented yogurt and milk, was lower. Mazorra-Manzano et al. (2021) suggested that fermented milk retains more bioactive compounds than cheeses due to increased proteolytic activity and the microbial fermentation process that releases bioactive peptides. However, the increase of the antioxidant activity is also related to the carotenoid content of the product.

3.3 CAROTENOID CONTENT

Table 2 shows the carotenoid content in the fresh cheese samples (control and with guabiroba pulp). In the control cheese, only β-carotene was found, which can be attributed to the whole milk used in its preparation. Chotyaku et al. (2014) reported that whole milk primarily contains the carotenoid β-carotene. This carotenoid comprises about 90% of the total carotenoids in cow's milk, making it the predominant type found in whole milk (Chotyaku et al., 2014). Habtegebriel et al. (2024) highlighted the importance of β-carotene as a precursor to vitamin A, and hence, a promoter of vision is well established. It is also the precursor of ligands necessary for nuclear receptors' activity in regulating energy metabolism. Besides their bioactive nature, they also impart an appealing color for food applications, and hence, they can be used as a food colorant. β-carotene is a very good candidate as an ingredient, given the increasing concern of consumers on the use of artificial food colorants (Habtegebriel et al., 2024). However, the greater the amount of guabiroba pulp added (5, 10, 15%), the higher ($p < 0.05$) the content of carotenoids (α-carotene, β-carotene, β-cryptoxanthin, and λ-carotene) found in the fresh cheese samples. This result showed an improvement in the nutritional value of fresh cheeses, which contributed to their yellow-reddish color.

Tabela 2 - Results obtained from the carotenoid content of fresh cheese formulation samples added to guabiroba pulp.

Carotenoid content	Samples			
	0	5	10	15
β-carotene (µg/g)	74.84 ± 0.01^{d}	77.85 ± 0.47^{c}	155.70 ± 0.93^{ab}	158.70 ± 1.40^{a}
α-carotene (µg/g)	< 0.001	27.51 ± 0.04^{c}	55.03 ± 0.09^{b}	82.54 ± 0.13^{a}
β-cryptoxanthin (µg/g)	< 0.001	31.88 ± 0.05^{c}	63.75 ± 0.80^{b}	95.63 ± 0.14^{a}
λ-carotene (µg/g)	< 0.001	20.50 ± 0.03^{c}	40.99 ± 0.06^{b}	61.49 ± 0.09^{a}

Sample 0 is the control sample (without guabiroba pulp); Sample 5 is the sample with 5% guabiroba pulp; Sample 10 is the sample with 10% guabiroba pulp; and Sample 15 is the sample with 15% guabiroba pulp. Results are expressed as mean ± standard deviation ($n = 3$). $^{a-c}$ Within a row, different lowercase letters indicate significant differences between samples ($p < 0.05$).

Source: Author (2025)

Olmedilla-Alonso et al. (2020) cited that the apparent bioavailability of α-carotene and β-cryptoxanthin is higher than that of β-carotene. Specifically, α-carotene shows 55% greater bioavailability, and β-cryptoxanthin shows 686% higher bioavailability compared to β-carotene when consumed in similar amounts. These authors also reported that these carotenoids are more efficiently absorbed and utilized by the body, besides emphasizing that both α-carotene and β-cryptoxanthin are significant contributors to vitamin A intake, often surpassing the contribution of retinol. This contribution is crucial for maintaining adequate vitamin A content for vision, immune function, and skin health (Olmedilla-Alonso et al., 2020). In addition to the nutritional value of the carotenoids in fresh cheeses, one cannot forget the potential of carotenoids as a natural antioxidant. Thus, the carotenoid content represented in this work by adding guabiroba to the fresh cheeses undoubtedly presents a nutritional highlight and functions as an antioxidant. Olmedilla-Alonso et al. (2020) stated that carotenoid content was used as a parameter to describe the antioxidant activity.

3.4 SUGAR ANALYSIS

The sugar content in fresh cheese samples is shown in Table 3. Sugars are important because they are basic nutrients necessary for the human body (Rybicka & Gliszczyńska-Świgło, 2021). However, a significant nutritional aspect of dairy products is the presence of lactose. Lactose is the primary sugar in milk and, consequently, in fresh cheeses. The lactose content present in cheeses depends on the type of cheese. Adding guabiroba pulp to the fresh cheeses produced did not influence the lactose content ($p > 0.05$). Determining the content of this sugar in dairy products is extremely important because lactose intolerance is a pathophysiological condition due to lactase (enzyme) deficiency. According to Suri et al. (2019), in this disorder, consuming lactose products causes lactose fermentation in the colon, leading to diarrhea and other clinical symptoms. Thus, fresh cheeses with or without adding guabiroba pulp (5, 10, 15%) are a source of lactose, which people with lactose intolerance should restrict.

Tabela 3 -Results of sugar content in fresh cheese formulations with guabiroba pulp.

Sugars content	Samples			
	0	5	10	15

Lactose (g/100g)	3.80±0.20^{a}	4.10 ± 0.10^{a}	3.99± 0.10^{a}	3.80 ± 0.10^{a}
Galactose (g/100g)	1.31±0.10^{a}	1.29 ± 0.10^{a}	1.28 ± 0.10^{a}	1.02 ± 0.10^{b}
Glucose (g/100g)	2.53±0.90^{a}	2.95 ± 0.40^{a}	2.94 ± 0.40^{a}	2.74 ± 0.40^{a}
Sucrose (g/100g)	1.12±0.30^{b}	1.24 ± 0.40^{ab}	1.44 ± 0.10^{a}	1.64 ± 0.30^{a}
Fructose (g/100g)	0.55±0.01^{b}	1.13 ± 0.40^{a}	1.37 ± 0.11^{a}	1.71 ± 0.47^{a}

Sample 0 is the control sample (without guabiroba pulp); Sample 5 is the sample with 5% guabiroba pulp; Sample 10 is the sample with 10% guabiroba pulp; and Sample 15 is the sample with 15% guabiroba pulp. Results are expressed as mean ± standard deviation (n = 3). $^{a-b}$ Within a row, different lowercase letters indicate significant differences between samples ($p < 0.05$).

Source: Author (2025)

One of the components of lactose is galactose. According to Garde et al. (2012), the cheese manufacturing process influences its presence in fresh cheeses, mainly the type of milk used and whether it is pasteurized. In the results obtained for galactose, it was found that only the use of 15% guabiroba pulp was responsible for the slight decrease ($p < 0.05$) in its content.

Regarding the glucose content, no change ($p > 0.05$) was observed in its content with the addition of guabiroba pulp (5, 10, 15%). Maintaining glucose content is especially important among the sugars evaluated in this study because, according to Rybicka and Gliszczyńska-Świgło (2021), it plays a significant role in brain and muscle function. Rybicka and Gliszczyńska-Świgło (2021) stated that fresh cheeses contain varying lactose, galactose, and glucose. These authors also confirmed that some cheeses contain fructose and sucrose. When guabiroba pulp was added to fresh cheeses, the same behavior was observed in sucrose and fructose content. Park et al. (2023) stated that fructose and sucrose play significant roles in foods as sweeteners, with fructose potentially offering benefits in glycemic control but posing risks to liver health when consumed in excess. Sucrose is a common dietary sugar with implications for energy intake and metabolic health, although its direct link to chronic disease is less clear when accounting for total caloric intake. Both sugars should be consumed in moderation, considering their metabolic effects and potential health impacts (Park et al., 2023).

3.5 HYDROPHILIC AND LIPOPHILIC COMPOUND DETERMINATION

Acquired values of hydrophilic and lipophilic compounds, containing their respective classes, in fresh cheese samples added with guabiroba pulp (5, 10, 15%) about fresh cheese without guabiroba pulp (Sample 0, control) are shown in Table 5. Thus, it was possible to verify that the increase in the guabiroba pulp increased ($p < 0.05$) the levels of hydrophilic and lipophilic compounds.

The hydrophilic compounds acquired as major components in the fresh cheese samples with the addition of guabiroba pulp were from the following classes: organic acid (citric acid, quinic acid, malic acid, and dehydroascorbic acid), cyclitol (myo-inositol), amino acid (4-hydroxy-1-methyl-proline), and sugar acid (glucuronic acid and gluconic acid). The other classes acquired showed lower expressivity than these previously cited classes. According to Jia et al. (2023), organic acids such as citric, quinic, malic, and dehydroascorbic acids are vital for metabolic processes and energy production and have various health benefits. These hydrophilic semi-volatile compounds contribute to the flavor and preservation of foods, aid in nutrient absorption, and have potential therapeutic roles in managing conditions like diabetes. The organic acid presence in fruits and other foods enhances nutritional value and functional properties (Jia et al., 2023). With the same nutritional importance, there was a gain in fresh cheese samples from the myo-inositol class represented by the compound cyclitol. Myo-inositol can improve metabolic parameters, potentially protecting the cardiovascular system.

Furthermore, cyclitol acts as a precursor for inositol triphosphate, which regulates hormones like insulin, contributing to its role in diabetes management (Antonowski et al., 2019). The amino acid class represented by the hydrophilic compound 4-hydroxy-1-methyl-proline) showed emphasis because this amino acid is involved in protein synthesis and may play a role in collagen stability (Wu, 2013), while glucuronic and gluconic acids support detoxification and metabolic processes (Mehtiö et al., 2016).

The lipophilic compound acquired as major components in samples of fresh cheeses added with guabiroba pulp (5, 10, 15%) was from the class fatty acids (octadenoic acid and n-9-(Z)-hexadecenoic acid). The other classes acquired showed lower expressivity than both cited classes. Octadecenoic acid and its isomers are important as they can serve as precursors to essential fatty acids like linoleic acid, which is vital for maintaining cell membrane integrity and producing signaling molecules. The n-9-(Z)-hexadecenoic acid and its isomer is a predominant form of hexadecenoic acid found in human depot fat. It is part of a mixture of positional isomers that contribute to the overall fatty acid profile in the body, potentially influencing metabolic processes and energy storage. Both octadecenoic and hexadecenoic acids are part of a broader group of fatty acids that exhibit bioactive properties. These include antioxidant, anti-inflammatory, and antimicrobial activities, crucial for preventing and managing various diseases (Morah et al., 2023).

Tabela 4- Content of the increase in hydrophilic and lipophilic compounds present in fresh cheese samples adding guabiroba pulp concerning the control sample.

		Content (µg/g)		
Class	**Hydrophilic compounds**	**Sample 5**	**Sample 10**	**Sample 15**
Amino acid	Glutamic acid	0.45 ± 0.05[c]	0.91 ± 0.10[b]	1.35 ± 0.10[a]
	4-amino-butanoic acid (GABA)	1.40 ± 0.07[c]	2.80 ± 0.13[b]	4.20 ± 0.20[a]
	4-hydroxy-1-methyl-proline (dimer)	19.10 ± 0.70[c]	38.00 ± 1.40[b]	57.15 ± 1.04[a]
Cyclitol	Myo-inositol	25.20 ± 2.25[c]	50.00 ± 2.30[b]	76.00 ± 2.79[a]
Organic acid	Citric acid	44.70 ± 0.97[c]	90.01 ± 1.50[b]	135.01 ± 6.07[a]
	Dehydroascorbic acid	2.75 ± 0.01[c]	5.04 ± 1.00[b]	8.31 ± 1.45[a]
	Glycolic acid	0.42 ± 0.02[c]	0.84 ± 0.03[b]	1.30 ± 0.05[a]
	Lactic acid	0.40 ± 0.03[c]	0.78 ± 0.06[b]	1.17 ± 0.17[a]
	Malic acid	6.29 ± 0.09[c]	12.60 ± 0.09[b]	19.00 ± 0.09[a]
	Quinic acid	10.81 ± 0.06[c]	21.50 ± 0.06[b]	33.01 ±0.07[a]
	Shikimic acid	0.40 ± 0.01[c]	0.73 ± 0.03[b]	1.10 ± 0.05[a]
	Succinic acid	0.33 ± 0.01[c]	0.70 ± 0.01[b]	2.50 ± 0.02[a]

Organic nitrogen	1-Pyrroline-3-hydroxy-5-carbocylic-acid	0.91 ± 0.01[c]	1.80 ± 0.01[b]	2.71 ± 0.06[a]
Sugar acid	Galacturonic acid	1.35 ± 0.06[c]	2.69 ± 0.02[b]	4.03 ± 0.04[a]
	Glyceric acid	1.58 ± 0.01[c]	3.16 ± 0.01[b]	4.57 ± 0.01[a]
	Gluconic acid	2.19 ± 0.01[c]	4.40 ± 0.01[b]	6.60 ± 0.08[a]
	Glucuronic acid	5.58 ± 0.05[c]	12.01 ± 1.00b	16.75 ±1.00[a]
Sugar alcohol	Arabitol	0.41 ± 0.04[c]	0.80 ± 0.09[b]	1.25 ± 0.13[a]
Class	**Lipophilic compounds**			
Aromatic	Benzoic acid	1.00 ± 0.03[c]	1.99 ± 0.09[b]	3.02 ± 0.09[a]
Fatty acid	n-9-(Z)-hexadecenoic acid	7.27 ± 0.07[c]	15.00 ± 0.15[b]	22.00 ± 0.22[a]
	Oleic acid	0.14 ± 0.01[c]	0.27 ± 0.03[b]	0.45 ± 0.05[a]
	Eicosanoic acid	0.45 ± 0.02[c]	1.00 ± 0.02[b]	1.40 ± 0.02[a]
	Hexadecanoic acid	0.58 ± 0.02[c]	1.17 ± 0.02[b]	1.75 ± 0.03[a]
	Octadenoic acid	21.48 ±0.01[c]	43.00 ± 0.05[b]	64.45 ± 1.62[a]

Sample 0 is the control sample (without guabiroba pulp); Sample 5 is the sample with 5% guabiroba pulp; Sample 10 is the sample with 10% guabiroba pulp; and Sample 15 is the sample with 15% guabiroba pulp. Results are expressed as mean ± standard deviation (n = 3). [a-c] Within a row, different lowercase letters indicate significant differences between samples ($p < 0.05$).

Source: Author (2025)

3.6 MULTI-ELEMENT PROFILE

Among the minerals found below the limit of detection for all fresh cheese samples (with or without the addition of guabiroba pulp) (Table 5), those identified as toxic in food are As (arsenic), Cd (cadmium), Pb (lead) and, to some extent, Cr (chromium) and Al (aluminum). Crupi et al. (2022) stated that arsenic, cadmium, and lead are toxic minerals in dairy products. According to Griboff et al. (2017), arsenic is considered toxic and poses a significant health risk. Cadmium is another toxic element because it can exceed toxicological limits, posing health risks (Bilandžić et al., 2021). Lead is consistently highlighted as a toxic element in cheese. Almášiová et al. (2024) emphasized that lead concentrations in cheese often exceed permissible limits, posing potential health risks to children. Lead can adversely affect the nervous system and kidneys, and its presence in cheese is a significant food safety concern. Aluminum and chromium are also noted for their potential toxicity, with hazard ratios indicating that they may be unsafe in certain scenarios (Almášiová et al., 2024). Therefore, continuous monitoring of these toxic elements ensures food safety and minimizes exposure to these toxic elements.

Tabela 5 -Results express **a** multi-element profile **of** fresh cheese formulations with guabiroba pulp.

Element	Samples			
s (mg/g)	0	5	10	15
Al	< LOD	< LOD	< LOD	< LOD
As	< LOD	< LOD	< LOD	< LOD
Ca	5.85±0.75[ac]	6.09 ± 0.11[a]	5.47 ± 0.40[abc]	4.92 ± 0.50[c]
Cd	< LOD	< LOD	< LOD	< LOD
Co	< LOD	< LOD	< LOD	< LOD
Cr	< LOD	< LOD	< LOD	< LOD
Cu	< LOD	< LOD	< LOD	< LOD
Fe	< LOD	< LOD	< LOD	< LOD

K	$1.00±0.12^{bc}$	$1.20 ± 0.02^{a}$	$1.16 ± 0.04^{ab}$	$1.01 ± 0.06^{c}$
Mg	$0.22± 0.01^{a}$	$0.30 ± 0.08^{a}$	$0.24 ± 0.01^{a}$	$0.23 ± 0.01^{a}$
Mn	< LOD	< LOD	< LOD	< LOD
Na	$3.30 ± 0.52^{d}$	$6.59 ± 0.11^{b}$	$7.08 ± 0.38^{a}$	$4.59 ± 0.25^{c}$
P	$4.39 ± 0.53^{ab}$	$4.65 ± 0.25^{a}$	$4.10 ± 0.29^{ab}$	$3.86 ± 0.13^{b}$
Pb	< LOD	< LOD	< LOD	< LOD
S	$1.89±0.19^{ab}$	$2.05 ± 0.10^{a}$	$1.80 ± 0.15^{b}$	$1.76 ± 0.02^{b}$
Se	< LOD	< LOD	< LOD	< LOD
Sr	$0.003±0.001^{a}$	$0.004±0.001^{a}$	$0.003±0.001^{a}$	$0.003±0.001^{a}$
Zn	$0.03±0.01^{a}$	$0.03±0.01^{a}$	$0.03±0.01^{a}$	$0.03±0.01^{a}$

Sample 0 is the control sample (without guabiroba pulp); Sample 5 is the sample with 5% guabiroba pulp; Sample 10 is the sample with 10% guabiroba pulp; and Sample 15 is the sample with 15% guabiroba pulp. Results are expressed as mean ± standard deviation (n = 3). [a-b] Within a row, different lowercase letters indicate significant differences between samples ($p < 0.05$). LOD is the limit of detection.

Source: Author (2025)

Regarding the other minerals found in all fresh cheese samples below the limit of detection, Co (cobalt), Cu (copper), Fe (iron), Mn (manganese), and Se (selenium) stood out. Contrary to what was found in the present study, iron, manganese, and copper are commonly found in various cheese types, including fresh cheeses. However, the results found in the present study corroborate those obtained by Deshwal et al. (2023). These authors reported that the concentration of the minerals copper, iron, and manganese can vary depending on the variety of cheese and production methods.

The amounts of guabiroba pulp added (5, 10, 15%) to fresh cheeses were also not able to influence the increase in the minerals cobalt and selenium (< LOD, limit of detection).

According to Crupi et al. (2022), both minerals are not typically detected in fresh cheeses. While it is present in some dairy products, these minerals are not commonly found in fresh cheese varieties (Crupi et al., 2022).

In general, the minerals calcium (Ca), magnesium (Mg), phosphorus (P), sulfur (S), strontium (Sr), and zinc (Zn) content remained unchanged in all samples of fresh cheeses prepared (with or without the addition of guabiroba pulp). Herman-Lara et al. (2019) highlighted that among these minerals, calcium, magnesium, and phosphorus are major minerals in fresh cheeses. These three minerals are essential for various bodily functions and are commonly found in dairy products, such as fresh cheeses (Herman-Lara et al., 2019). Falcão et al. (2023) stated that sulfur is also present in fresh cheeses, often as part of amino acids and proteins, while zinc is a trace element found in fresh cheeses, contributing to various enzymatic functions in the body. However, the small contents of the mineral strontium in the cheese samples agree with the result observed by Herman-Lara et al. (2019). These authors affirmed that, while strontium can be present in some cheeses, it is not typically highlighted as a common mineral in fresh cheeses, suggesting it may be negligible in many fresh cheese varieties.

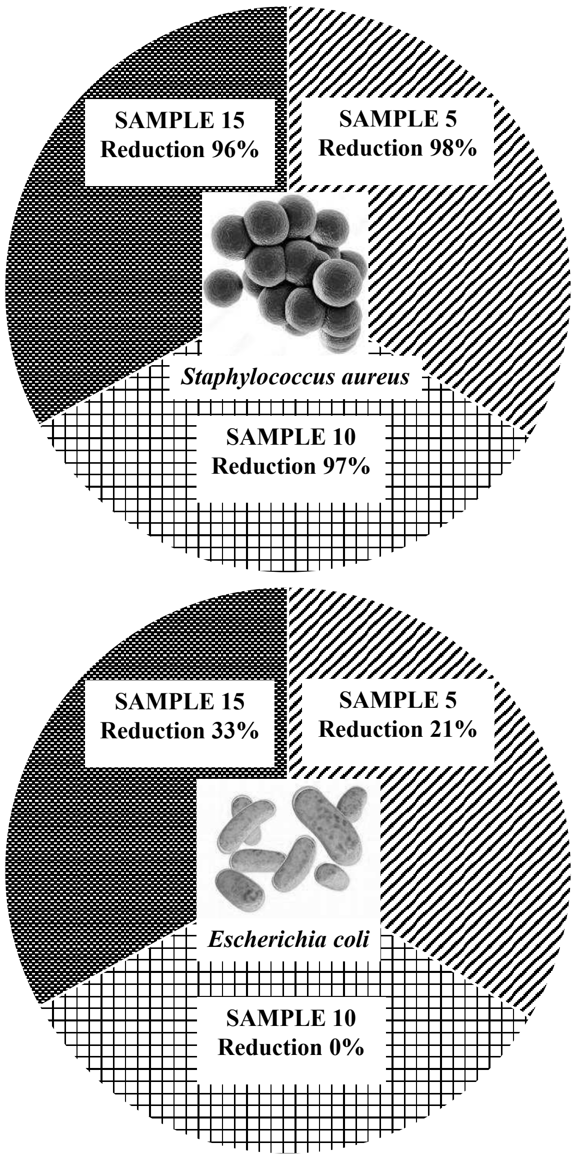
Regarding the potassium (K) content of the cheese samples, a slight decrease ($p < 0.05$) was observed in the fresh cheese added with 15% guabiroba pulp. On the other hand, it was found that all samples of fresh cheeses presented differences in the sodium (Na) content. According to Tidona et al. (2022), the variability in sodium content in fresh cheeses is primarily due to the multifaceted role of salt in cheese-making. However, efforts to reduce sodium while maintaining quality are ongoing, reflecting technological challenges and consumer demand (Tidona et al., 2022). Thus, it is worth highlighting that the sodium content in all cheeses produced was low, representing less than the recommended daily intake. There is an international consensus about a decrease in sodium consumption. The World Health Organization (WHO) proposes to reduce the consumption of sodium by 30% (from 2,000 mg sodium per day to < 800 mg sodium per day until 2025) (WHO, 2023). According to the WHO (2023), sodium is an essential nutrient for maintaining plasma volume, acid-base balance, transmission of nerve impulses, and normal cell function; sodium deficiency is extremely unlikely in healthy individuals. However, excess sodium is linked to adverse health outcomes, including increased blood pressure. It is also known that a simple reduction of salt in cheesemaking can negatively impact the safety of the final product. To overcome such challenges, Falih et al. (2024) proposed using modified and vacuum packaging and active and intelligent packaging as an alternative to ensure safety in reduced sodium fresh cheese. These authors also highlighted that fresh cheeses are not ripening; they are immediately consumed fresh for mild flavor.

Despite having a modest contribution concerning the multi-element profile of the fresh cheeses produced, it was possible to note that this information is useful for dietary planning and understanding the nutritional profile of fresh cheeses, as well as the safety of consuming them about the presence of the main toxic minerals. The results found in the present study highlighted that their multi-element profile was not able to reduce the importance of the addition of guabiroba pulp (5, 10, 15%) because of the increase observed for total phenolic compounds, *in vitro* antioxidant capacity and carotenoid contents.

3.7 ANTIMICROBIAL ACTIVITY

Fig 3 shows the results obtained for the reduction of *Staphylococcus aureus* and *Escherichia coli* in fresh cheese samples added with 5% guabiroba pulp (Sample 5), 10% guabiroba pulp (Sample 10), and 15% guabiroba pulp (Sample 15). It was possible to verify a representative reduction of *S. aureus* in all samples containing guabiroba pulp (5, 10, 15%). The genus *Staphylococcus* is made up of 52 species. *S. aureus* is one of the species most regularly associated with human pathologies. *S. aureus* mainly causes nosocomial infections associated with pneumonia and other respiratory and cardiovascular infections (Abad et al., 2024). Some strains of *S. aureus* produce enterotoxins that cause staphylococcal food poisoning. The foods mainly involved in food poisoning of this type are milk and dairy products. Poisoning occurs due to ingesting enterotoxins produced in food and improper handling and storage at high temperatures (Abad et al., 2024, Abril et al., 2020). Similar results were found by Dias-Souza et al. (2018), who verified that fruit pulp, specifically açaí pulp, could effectively inhibit *Staphylococcus aureus* in dairy products. Fiebig et al. (2024) observed that pinhão had a promising potential as a novel for pathogenic decrease in yogurt due to the relation with phenolic compounds. These authors also cited studies about the relationship between phenolic compounds and their antimicrobial properties. Miklasińska-Majdanik et al. (2018) reported that the mechanisms of action of phenolic compounds on bacterial cells have been partially attributed to damage to the bacterial membrane, inhibition of virulence factors such as enzymes and toxins, and suppression of bacterial biofilm formation. These authors concluded that phenolic hydroxyl groups, which have a high affinity for proteins, and microbial enzyme inhibition may enhance the antibacterial effects.

Figure 3 - Reduction (%) of *Staphylococcus aureus* and *Escherichia coli* in fresh cheese samples added with 5% guabiroba pulp (Sample 5), 10% guabiroba pulp (Sample 10) and 15% guabiroba pulp (Sample 15).



Source: Author (2025).

Miklasińska-Majdanik et al. (2018) emphasized that numerous reports indicate that plant compounds combined with commonly used antibacterial drugs may constitute a new strategy against infections caused by multi-drug resistant bacteria. It has been documented that plant-derived such as phenolic compounds demonstrate antimicrobial properties against a broad spectrum of microorganisms that sensitize multi-drug resistance strains to bactericidal or bacteriostatic antibiotics (Miklasińska-Majdanik et al., 2018).

As phenolic compounds have shown antimicrobial activity against gram-positive bacteria (*S. aureus*), they have also been credited with antimicrobial activity against *E. coli*, a gram-negative bacterium (Fig. 3). However, the reduction was not as significant as that found for *S. aureus*. Dubreuil (2020) credited the antimicrobial activity of some fruits rich in phenolic compounds to bacterial membrane damage, suppression of virulence factors targeting enzymes and toxins, and inhibition of biofilm formation. Cahyani et al. (2024) and Banu and Manda (2019) found that pineapple peel extract and pomegranate fruit exhibited antimicrobial activity against *E. coli*, respectively.

Dubreuil (2020) highlighted that *E. coli* is a major cause of diarrhea and is responsible for extraintestinal infections in humans and animals. This author also reported that antibiotics have been used to control infections caused by *E. coli*. However, resistance was observed with many strains. Therefore, fruit pulp represents a source of bioactive compounds, such as total phenolic compounds, that could also be beneficial in controlling infectious diseases caused by *E. coli*. These compounds have behavior bacteriostatic or bactericidal potential or can be used as synergic agents to amplify the activity of antibiotics for which the germs present some resistance (Dubreuil, 2020). These behaviors may also be associated with the effect of phenolic compounds against *S. aureus*.

4 CONCLUSION

The gradual increase in guabiroba pulp (5, 10, 15%) resulted in fresh cheeses with lower water activity values. Another decrease was observed in the pH of the fresh cheese samples with 15% of guabiroba pulp. However, protein, moisture, and titratable acidity contents did not change. On the other hand, the guabiroba pulp (5, 10, 15%) contributed to the increase ($p < 0.05$) in the ash content of the fresh cheese samples. The increase in the addition of guabiroba pulp decreased the lightness and increased the tendency towards a yellow-reddish hue of the fresh cheeses. The difference in color of the cheeses was evident to the naked eye. Adding guabiroba pulp resulted in fresh cheeses with lower firmness, elasticity, cohesiveness, and gumminess. Among the samples of fresh cheeses with guabiroba pulp, it was possible to verify that the firmness and gumminess decreased with 10% of guabiroba pulp. In comparison, the elasticity decreased with 15% of the pulp. However, no influence was verified in the cohesiveness of the fresh cheeses with guabiroba pulp addition. Adding guabiroba pulp increased the total phenolic compounds in the fresh cheese samples. Using $\geq 10\%$ of guabiroba pulp does not interfere with the content of total phenolic compounds of the fresh cheeses.

Regarding the *in vitro* antioxidant capacity, increases in the antioxidant activity were observed, along with a progressive increase in the guabiroba pulp added. As well as the increase in the yellow-reddish color of the fresh cheeses with guabiroba pulp, an increase in the content of carotenoids (α-carotene, β-carotene, β-cryptoxanthin, and λ-carotene) was verified. The sugar content in the fresh cheese samples was represented by lactose, galactose, glucose, sucrose, and fructose. Thus, fresh cheeses with or without adding guabiroba pulp (5, 10, 15%) are a source of lactose, which people with lactose intolerance should restrict. Of the sugars evaluated in the present study, only galactose had a decreased content when 15% of guabiroba pulp was added. The hydrophilic compounds acquired as major components with high expressivity in the fresh cheese samples with the addition of guabiroba pulp were organic acid (citric acid, quinic acid, malic acid, and dehydroascorbic acid) > cyclitol (myo-inositol) > amino acid (4-hydroxy-1-methyl-proline) > sugar acid (glucuronic acid and gluconic acid). The lipophilic compound acquired as a major component in samples of fresh cheeses with the addition of guabiroba pulp was from the class of fatty acids (octadenoic acid and n-9-(Z)-hexadecenoic acid). The multielement profile of fresh cheeses with or without the addition of guabiroba pulp was represented by the increasing presence of Ca > P > S > K > Mg > Zn > Sr. In contrast, toxic minerals were not detected in the cheese samples. In addition to these facts, reductions in *Staphylococcus aureus* (96 to 98%) and *Escherichia coli* (21-33%) were observed for fresh cheese samples with the addition of guabiroba than fresh cheese samples without guabiroba pulp. Thus, greater antimicrobial activity was observed for *S. aureus* strain. Among the aspects that stood out in the fresh cheeses were the total phenolic compounds, the antioxidant activity, the carotenoid contents, and the acquisition of hydrophilic and lipophilic compounds. However, the other analyses performed on the fresh cheeses did not generate uncertainty about using guabiroba pulp in obtaining functional fresh cheeses. Finally, it was possible to find potential applications of guabiroba pulp (5, 10, 15%) to obtain functional fresh cheeses.

Credit author statement

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Methodology, Validation, Visualization. Marcel Afonso Provenzi: Data curation, Formal analysis, Investigation, Methodology, Validation. Marília Miotto: Data curation, Formal analysis, Investigation, Methodology, Validation. Cristiane Vieira Helm: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Validation, Visualization, Writing - original draft, Writing - review and editing. Elane Schwinden Prudencio: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Supervision, Validation, Visualization, Writing – original draft, Writing – review and editing.

Declaration of competing interest

There are no conflicts of interest to declare for the current work.

Data availability

No data was used for the research described in the article.

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ANEXO A – COMPROVANTE DE SUBMISSÃO – CAPÍTULO 2

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Title
The potential of guabiroba (Campomanesia xanthocarpa O. Berg) pulp as a functional ingredient aiming to increase the nutritional dulce de leche properties

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Date Submitted
21-Nov-2024

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ANEXO B – COMPROVANTE DE SUBMISSÃO – CAPÍTULO 3

Food Research International

The potential of guabiroba pulp application and its effects aiming at the elaboration of functional fresh cheeses

--Manuscript Draft--

Manuscript Number:	
Article Type:	Research Paper
Section/Category:	Functional Foods
Keywords:	Campomanesia xanthocarpa O. Berg; Bioactive compounds; Functional food; Dairy product; Innovative food.
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Abstract:	Fresh cheeses are dairy products that consumers consider highly acceptable, even more so when functional properties are added to them. This study aimed to add guabiroba pulp (5, 10, 15%) in fresh cheeses. This way, fresh cheeses were characterized by their physical-chemical properties, color, texture, total phenolic compounds, in vitro antioxidant activity, sugars, hydrophilic and lipophilic compounds, multi-element profile, and antimicrobial activity. Adding guabiroba pulp decreased water activity, ash content, and pH value. The guabiroba pulp also reduced the lightness of the fresh cheeses, and its addition resulted in cheeses with a hue visible to the naked eye, tending towards yellow-reddish. Guabiroba pulp addition decreased firmness, elasticity, and gumminess. It was evident that using guabiroba pulp increased the total content of phenolic compounds, the in vitro antioxidant activity, and the carotenoid content. All fresh cheese was represented by lactose, galactose, glucose, sucrose, and fructose. The hydrophilic compounds acquired as important components with high expression in the fresh cheese samples with adding guabiroba pulp were organic acids > cyclitol > amino acids > sugar acid. In contrast, the lipophilic compound was the fatty acid class. The multi-element profile of fresh cheeses was represented by Ca > P > S > K > Mg > Zn > Sr. In contrast, toxic minerals were not detected in the cheese samples. Antimicrobial activity against Staphylococcus aureus and Escherichia coli was observed for fresh cheese samples with guabiroba pulp addition. In the present study, guabiroba pulp content is recommended to be between 10- 15%.