

A Química nas Áreas Natural, Tecnológica e Sustentável

3

Érica de Melo Azevedo
(Organizadora)



A Química nas Áreas Natural, Tecnológica e Sustentável

3

Érica de Melo Azevedo
(Organizadora)



Editora Chefe

Profª Drª Antonella Carvalho de Oliveira

Assistentes Editoriais

Natalia Oliveira

Bruno Oliveira

Flávia Roberta Barão

Bibliotecário

Maurício Amormino Júnior

Projeto Gráfico e Diagramação

Natália Sandrini de Azevedo

Camila Alves de Cremo

Karine de Lima Wisniewski

Luiza Alves Batista

Maria Alice Pinheiro

Imagens da Capa

Shutterstock

Edição de Arte

Luiza Alves Batista

Revisão

Os Autores

2020 by Atena Editora

Copyright © Atena Editora

Copyright do Texto © 2020 Os autores

Copyright da Edição © 2020 Atena Editora

Direitos para esta edição cedidos à Atena Editora pelos autores.



Todo o conteúdo deste livro está licenciado sob uma Licença de Atribuição *Creative Commons*. Atribuição 4.0 Internacional (CC BY 4.0).

O conteúdo dos artigos e seus dados em sua forma, correção e confiabilidade são de responsabilidade exclusiva dos autores, inclusive não representam necessariamente a posição oficial da Atena Editora. Permitido o *download* da obra e o compartilhamento desde que sejam atribuídos créditos aos autores, mas sem a possibilidade de alterá-la de nenhuma forma ou utilizá-la para fins comerciais.

A Atena Editora não se responsabiliza por eventuais mudanças ocorridas nos endereços convencionais ou eletrônicos citados nesta obra.

Todos os manuscritos foram previamente submetidos à avaliação cega pelos pares, membros do Conselho Editorial desta Editora, tendo sido aprovados para a publicação.

Conselho Editorial

Ciências Humanas e Sociais Aplicadas

Prof. Dr. Álvaro Augusto de Borba Barreto – Universidade Federal de Pelotas

Prof. Dr. Alexandre Jose Schumacher – Instituto Federal de Educação, Ciência e Tecnologia do Paraná

Prof. Dr. Américo Junior Nunes da Silva – Universidade do Estado da Bahia

Prof. Dr. Antonio Carlos Frasson – Universidade Tecnológica Federal do Paraná

Prof. Dr. Antonio Gasparetto Júnior – Instituto Federal do Sudeste de Minas Gerais

Prof. Dr. Antonio Isidro-Filho – Universidade de Brasília

Prof. Dr. Carlos Antonio de Souza Moraes – Universidade Federal Fluminense
Profª Drª Cristina Gaio – Universidade de Lisboa
Prof. Dr. Daniel Richard Sant’Ana – Universidade de Brasília
Prof. Dr. Deyvison de Lima Oliveira – Universidade Federal de Rondônia
Profª Drª Dilma Antunes Silva – Universidade Federal de São Paulo
Prof. Dr. Edvaldo Antunes de Farias – Universidade Estácio de Sá
Prof. Dr. Elson Ferreira Costa – Universidade do Estado do Pará
Prof. Dr. Eloi Martins Senhora – Universidade Federal de Roraima
Prof. Dr. Gustavo Henrique Cepolini Ferreira – Universidade Estadual de Montes Claros
Profª Drª Ivone Goulart Lopes – Istituto Internazionele delle Figlie de Maria Ausiliatrice
Prof. Dr. Jadson Correia de Oliveira – Universidade Católica do Salvador
Prof. Dr. Julio Candido de Meirelles Junior – Universidade Federal Fluminense
Profª Drª Lina Maria Gonçalves – Universidade Federal do Tocantins
Prof. Dr. Luis Ricardo Fernandes da Costa – Universidade Estadual de Montes Claros
Profª Drª Natiéli Piovesan – Instituto Federal do Rio Grande do Norte
Prof. Dr. Marcelo Pereira da Silva – Pontifícia Universidade Católica de Campinas
Profª Drª Maria Luzia da Silva Santana – Universidade Federal de Mato Grosso do Sul
Profª Drª Paola Andressa Scortegagna – Universidade Estadual de Ponta Grossa
Profª Drª Rita de Cássia da Silva Oliveira – Universidade Estadual de Ponta Grossa
Prof. Dr. Rui Maia Diamantino – Universidade Salvador
Prof. Dr. Urandi João Rodrigues Junior – Universidade Federal do Oeste do Pará
Profª Drª Vanessa Bordin Viera – Universidade Federal de Campina Grande
Prof. Dr. William Cleber Domingues Silva – Universidade Federal Rural do Rio de Janeiro
Prof. Dr. Willian Douglas Guilherme – Universidade Federal do Tocantins

Ciências Agrárias e Multidisciplinar

Prof. Dr. Alexandre Igor Azevedo Pereira – Instituto Federal Goiano
Profª Drª Carla Cristina Bauermann Brasil – Universidade Federal de Santa Maria
Prof. Dr. Antonio Pasqualetto – Pontifícia Universidade Católica de Goiás
Prof. Dr. Cleberton Correia Santos – Universidade Federal da Grande Dourados
Profª Drª Daiane Garabeli Trojan – Universidade Norte do Paraná
Profª Drª Diocléa Almeida Seabra Silva – Universidade Federal Rural da Amazônia
Prof. Dr. Écio Souza Diniz – Universidade Federal de Viçosa
Prof. Dr. Fábio Steiner – Universidade Estadual de Mato Grosso do Sul
Prof. Dr. Fágner Cavalcante Patrocínio dos Santos – Universidade Federal do Ceará
Profª Drª Girlene Santos de Souza – Universidade Federal do Recôncavo da Bahia
Prof. Dr. Jael Soares Batista – Universidade Federal Rural do Semi-Árido
Prof. Dr. Júlio César Ribeiro – Universidade Federal Rural do Rio de Janeiro
Profª Drª Lina Raquel Santos Araújo – Universidade Estadual do Ceará
Prof. Dr. Pedro Manuel Villa – Universidade Federal de Viçosa
Profª Drª Raissa Rachel Salustriano da Silva Matos – Universidade Federal do Maranhão
Prof. Dr. Ronilson Freitas de Souza – Universidade do Estado do Pará
Profª Drª Talita de Santos Matos – Universidade Federal Rural do Rio de Janeiro
Prof. Dr. Tiago da Silva Teófilo – Universidade Federal Rural do Semi-Árido
Prof. Dr. Valdemar Antonio Paffaro Junior – Universidade Federal de Alfenas

Ciências Biológicas e da Saúde

Prof. Dr. André Ribeiro da Silva – Universidade de Brasília
Prof^ª Dr^ª Anelise Levay Murari – Universidade Federal de Pelotas
Prof. Dr. Benedito Rodrigues da Silva Neto – Universidade Federal de Goiás
Prof^ª Dr^ª Débora Luana Ribeiro Pessoa – Universidade Federal do Maranhão
Prof. Dr. Douglas Siqueira de Almeida Chaves -Universidade Federal Rural do Rio de Janeiro
Prof. Dr. Edson da Silva – Universidade Federal dos Vales do Jequitinhonha e Mucuri
Prof^ª Dr^ª Eleuza Rodrigues Machado – Faculdade Anhanguera de Brasília
Prof^ª Dr^ª Elane Schwinden Prudêncio – Universidade Federal de Santa Catarina
Prof^ª Dr^ª Eysler Gonçalves Maia Brasil – Universidade da Integração Internacional da Lusofonia Afro-Brasileira
Prof. Dr. Ferlando Lima Santos – Universidade Federal do Recôncavo da Bahia
Prof^ª Dr^ª Gabriela Vieira do Amaral – Universidade de Vassouras
Prof. Dr. Gianfábio Pimentel Franco – Universidade Federal de Santa Maria
Prof. Dr. Helio Franklin Rodrigues de Almeida – Universidade Federal de Rondônia
Prof^ª Dr^ª Iara Lúcia Tescarollo – Universidade São Francisco
Prof. Dr. Igor Luiz Vieira de Lima Santos – Universidade Federal de Campina Grande
Prof. Dr. Jefferson Thiago Souza – Universidade Estadual do Ceará
Prof. Dr. Jesus Rodrigues Lemos – Universidade Federal do Piauí
Prof. Dr. Jônatas de França Barros – Universidade Federal do Rio Grande do Norte
Prof. Dr. José Max Barbosa de Oliveira Junior – Universidade Federal do Oeste do Pará
Prof. Dr. Luís Paulo Souza e Souza – Universidade Federal do Amazonas
Prof^ª Dr^ª Magnólia de Araújo Campos – Universidade Federal de Campina Grande
Prof. Dr. Marcus Fernando da Silva Praxedes – Universidade Federal do Recôncavo da Bahia
Prof^ª Dr^ª Mylena Andréa Oliveira Torres – Universidade Ceuma
Prof^ª Dr^ª Natiéli Piovesan – Instituto Federaci do Rio Grande do Norte
Prof. Dr. Paulo Inada – Universidade Estadual de Maringá
Prof. Dr. Rafael Henrique Silva – Hospital Universitário da Universidade Federal da Grande Dourados
Prof^ª Dr^ª Regiane Luz Carvalho – Centro Universitário das Faculdades Associadas de Ensino
Prof^ª Dr^ª Renata Mendes de Freitas – Universidade Federal de Juiz de Fora
Prof^ª Dr^ª Vanessa Lima Gonçalves – Universidade Estadual de Ponta Grossa
Prof^ª Dr^ª Vanessa Bordin Viera – Universidade Federal de Campina Grande

Ciências Exatas e da Terra e Engenharias

Prof. Dr. Adélio Alcino Sampaio Castro Machado – Universidade do Porto
Prof. Dr. Alexandre Leite dos Santos Silva – Universidade Federal do Piauí
Prof. Dr. Carlos Eduardo Sanches de Andrade – Universidade Federal de Goiás
Prof^ª Dr^ª Carmen Lúcia Voigt – Universidade Norte do Paraná
Prof. Dr. Douglas Gonçalves da Silva – Universidade Estadual do Sudoeste da Bahia
Prof. Dr. Eloi Rufato Junior – Universidade Tecnológica Federal do Paraná
Prof. Dr. Fabrício Menezes Ramos – Instituto Federal do Pará
Prof^ª Dra. Jéssica Verger Nardeli – Universidade Estadual Paulista Júlio de Mesquita Filho
Prof. Dr. Juliano Carlo Rufino de Freitas – Universidade Federal de Campina Grande
Prof^ª Dr^ª Luciana do Nascimento Mendes – Instituto Federal de Educação, Ciência e Tecnologia do Rio Grande do Norte
Prof. Dr. Marcelo Marques – Universidade Estadual de Maringá

Profª Drª Neiva Maria de Almeida – Universidade Federal da Paraíba
Profª Drª Natiéli Piovesan – Instituto Federal do Rio Grande do Norte
Prof. Dr. Takeshy Tachizawa – Faculdade de Campo Limpo Paulista

Linguística, Letras e Artes

Profª Drª Adriana Demite Stephani – Universidade Federal do Tocantins
Profª Drª Angeli Rose do Nascimento – Universidade Federal do Estado do Rio de Janeiro
Profª Drª Carolina Fernandes da Silva Mandaji – Universidade Tecnológica Federal do Paraná
Profª Drª Denise Rocha – Universidade Federal do Ceará
Prof. Dr. Fabiano Tadeu Grazioli – Universidade Regional Integrada do Alto Uruguai e das Missões
Prof. Dr. Gilmei Fleck – Universidade Estadual do Oeste do Paraná
Profª Drª Keyla Christina Almeida Portela – Instituto Federal de Educação, Ciência e Tecnologia do Paraná
Profª Drª Miranilde Oliveira Neves – Instituto de Educação, Ciência e Tecnologia do Pará
Profª Drª Sandra Regina Gardacho Pietrobon – Universidade Estadual do Centro-Oeste
Profª Drª Sheila Marta Carregosa Rocha – Universidade do Estado da Bahia

Conselho Técnico Científico

Prof. Me. Abrãao Carvalho Nogueira – Universidade Federal do Espírito Santo
Prof. Me. Adalberto Zorzo – Centro Estadual de Educação Tecnológica Paula Souza
Prof. Me. Adalto Moreira Braz – Universidade Federal de Goiás
Prof. Dr. Adaylson Wagner Sousa de Vasconcelos – Ordem dos Advogados do Brasil/Seccional Paraíba
Prof. Dr. Adilson Tadeu Basquerote Silva – Universidade para o Desenvolvimento do Alto Vale do Itajaí
Prof. Me. Alexsandro Teixeira Ribeiro – Centro Universitário Internacional
Prof. Me. André Flávio Gonçalves Silva – Universidade Federal do Maranhão
Profª Ma. Anne Karynne da Silva Barbosa – Universidade Federal do Maranhão
Profª Drª Andreza Lopes – Instituto de Pesquisa e Desenvolvimento Acadêmico
Profª Drª Andrezza Miguel da Silva – Faculdade da Amazônia
Prof. Dr. Antonio Hot Pereira de Faria – Polícia Militar de Minas Gerais
Prof. Me. Armando Dias Duarte – Universidade Federal de Pernambuco
Profª Ma. Bianca Camargo Martins – UniCesumar
Profª Ma. Carolina Shimomura Nanya – Universidade Federal de São Carlos
Prof. Me. Carlos Antônio dos Santos – Universidade Federal Rural do Rio de Janeiro
Prof. Ma. Cláudia de Araújo Marques – Faculdade de Música do Espírito Santo
Profª Drª Cláudia Taís Siqueira Cagliari – Centro Universitário Dinâmica das Cataratas
Prof. Me. Clécio Danilo Dias da Silva – Universidade Federal do Rio Grande do Norte
Prof. Me. Daniel da Silva Miranda – Universidade Federal do Pará
Profª Ma. Daniela da Silva Rodrigues – Universidade de Brasília
Profª Ma. Daniela Remião de Macedo – Universidade de Lisboa
Profª Ma. Dayane de Melo Barros – Universidade Federal de Pernambuco
Prof. Me. Douglas Santos Mezacas – Universidade Estadual de Goiás
Prof. Me. Edevaldo de Castro Monteiro – Embrapa Agrobiologia
Prof. Me. Eduardo Gomes de Oliveira – Faculdades Unificadas Doctum de Cataguases
Prof. Me. Eduardo Henrique Ferreira – Faculdade Pitágoras de Londrina

Prof. Dr. Edwaldo Costa – Marinha do Brasil
Prof. Me. Eliel Constantino da Silva – Universidade Estadual Paulista Júlio de Mesquita
Prof. Me. Ernane Rosa Martins – Instituto Federal de Educação, Ciência e Tecnologia de Goiás
Prof. Me. Euvaldo de Sousa Costa Junior – Prefeitura Municipal de São João do Piauí
Profª Ma. Fabiana Coelho Couto Rocha Corrêa – Centro Universitário Estácio Juiz de Fora
Prof. Dr. Fabiano Lemos Pereira – Prefeitura Municipal de Macaé
Prof. Me. Felipe da Costa Negrão – Universidade Federal do Amazonas
Profª Drª Germana Ponce de Leon Ramírez – Centro Universitário Adventista de São Paulo
Prof. Me. Gevair Campos – Instituto Mineiro de Agropecuária
Prof. Dr. Guilherme Renato Gomes – Universidade Norte do Paraná
Prof. Me. Gustavo Krahl – Universidade do Oeste de Santa Catarina
Prof. Me. Helton Rangel Coutinho Junior – Tribunal de Justiça do Estado do Rio de Janeiro
Profª Ma. Isabelle Cerqueira Sousa – Universidade de Fortaleza
Profª Ma. Jaqueline Oliveira Rezende – Universidade Federal de Uberlândia
Prof. Me. Javier Antonio Albornoz – University of Miami and Miami Dade College
Prof. Me. Jhonatan da Silva Lima – Universidade Federal do Pará
Prof. Dr. José Carlos da Silva Mendes – Instituto de Psicologia Cognitiva, Desenvolvimento Humano e Social
Prof. Me. Jose Elyton Batista dos Santos – Universidade Federal de Sergipe
Prof. Me. José Luiz Leonardo de Araujo Pimenta – Instituto Nacional de Investigación Agropecuaria Uruguay
Prof. Me. José Messias Ribeiro Júnior – Instituto Federal de Educação Tecnológica de Pernambuco
Profª Drª Juliana Santana de Curcio – Universidade Federal de Goiás
Profª Ma. Juliana Thaisa Rodrigues Pacheco – Universidade Estadual de Ponta Grossa
Profª Drª Kamilly Souza do Vale – Núcleo de Pesquisas Fenomenológicas/UFPA
Prof. Dr. Kárpio Márcio de Siqueira – Universidade do Estado da Bahia
Profª Drª Karina de Araújo Dias – Prefeitura Municipal de Florianópolis
Prof. Dr. Lázaro Castro Silva Nascimento – Laboratório de Fenomenologia & Subjetividade/UFPR
Prof. Me. Leonardo Tullio – Universidade Estadual de Ponta Grossa
Profª Ma. Lillian Coelho de Freitas – Instituto Federal do Pará
Profª Ma. Liliani Aparecida Sereno Fontes de Medeiros – Consórcio CEDERJ
Profª Drª Lívia do Carmo Silva – Universidade Federal de Goiás
Prof. Dr. Lucio Marques Vieira Souza – Secretaria de Estado da Educação, do Esporte e da Cultura de Sergipe
Prof. Me. Luis Henrique Almeida Castro – Universidade Federal da Grande Dourados
Prof. Dr. Luan Vinicius Bernardelli – Universidade Estadual do Paraná
Prof. Dr. Michel da Costa – Universidade Metropolitana de Santos
Prof. Dr. Marcelo Máximo Purificação – Fundação Integrada Municipal de Ensino Superior
Prof. Me. Marcos Aurelio Alves e Silva – Instituto Federal de Educação, Ciência e Tecnologia de São Paulo
Profª Ma. Maria Elanny Damasceno Silva – Universidade Federal do Ceará
Profª Ma. Marileila Marques Toledo – Universidade Federal dos Vales do Jequitinhonha e Mucuri
Prof. Me. Ricardo Sérgio da Silva – Universidade Federal de Pernambuco
Profª Ma. Renata Luciane Polsaque Young Blood – UniSecal

Prof. Me. Robson Lucas Soares da Silva – Universidade Federal da Paraíba
Prof. Me. Sebastião André Barbosa Junior – Universidade Federal Rural de Pernambuco
Profª Ma. Silene Ribeiro Miranda Barbosa – Consultoria Brasileira de Ensino, Pesquisa e Extensão
Profª Ma. Solange Aparecida de Souza Monteiro – Instituto Federal de São Paulo
Prof. Me. Tallys Newton Fernandes de Matos – Faculdade Regional Jaguaribana
Profª Ma. Thatianny Jasmine Castro Martins de Carvalho – Universidade Federal do Piauí
Prof. Me. Tiago Silvio Dedoné – Colégio ECEL Positivo
Prof. Dr. Welleson Feitosa Gazel – Universidade Paulista

Editora Chefe: Profª Drª Antonella Carvalho de Oliveira
Bibliotecário Maurício Amormino Júnior
Diagramação: Camila Alves de Cremona
Edição de Arte: Luiza Alves Batista
Revisão: Os Autores
Organizadora: Érica de Melo Azevedo

Dados Internacionais de Catalogação na Publicação (CIP)
(eDOC BRASIL, Belo Horizonte/MG)

Q6 A química nas áreas natural, tecnológica e sustentável 3
 [recurso eletrônico] / Organizadora Érica de Melo
 Azevedo. – Ponta Grossa, PR: Atena, 2020.

Formato: PDF

Requisitos de sistemas: Adobe Acrobat Reader

Modo de acesso: World Wide Web

Inclui bibliografia

ISBN 978-65-5706-384-2

DOI 10.22533/at.ed.842201709

1. Química – Pesquisa – Brasil. 2. Tecnologia. 3.
 Sustentabilidade. I. Azevedo, Érica de Melo.

CDD 540

Elaborado por Maurício Amormino Júnior – CRB6/2422

Atena Editora

Ponta Grossa – Paraná – Brasil

Telefone: +55 (42) 3323-5493

www.atenaeditora.com.br

contato@atenaeditora.com.br

APRESENTAÇÃO

A Coleção “A Química nas Áreas Natural, Tecnológica e Sustentável” apresenta artigos de pesquisa na área de química e que envolvem conceitos de sustentabilidade, tecnologia, ensino e ciências naturais. A obra contém 69 artigos, que estão distribuídos em 3 volumes. No volume 1 são apresentados 29 capítulos sobre aplicações e desenvolvimentos de materiais adsorventes sustentáveis e polímeros biodegradáveis; o volume 2 reúne 20 capítulos sobre o desenvolvimento de materiais alternativos para tratamento de água e efluentes e propostas didáticas para ensino das temáticas em questão. No volume 3 estão compilados 20 capítulos que incluem artigos sobre óleos essenciais, produtos naturais e diferentes tipos de combustíveis.

Os objetivos principais da presente coleção são apresentar aos leitores diferentes aspectos das aplicações e pesquisas de química e de suas áreas correlatas no desenvolvimento de tecnologias e materiais que promovam a sustentabilidade e o ensino de química de forma transversal e lúdica.

Os artigos constituintes da coleção podem ser utilizados para o desenvolvimento de projetos de pesquisa, para o ensino dos temas abordados e até mesmo para a atualização do estado da arte nas áreas de adsorventes, polímeros, análise e tratamento de água e efluentes, propostas didáticas para ensino de química, óleos essenciais, produtos naturais e combustíveis.

Após esta apresentação, convido os leitores a apreciarem e consultarem, sempre que necessário, a coleção “A Química nas áreas natural, tecnológica e Sustentável”. Desejo uma excelente leitura!

Érica de Melo Azevedo

SUMÁRIO

CAPÍTULO 1..... 1

AMIDO HIDROFOBICAMENTE MODIFICADO PARA APLICAÇÃO NA INDÚSTRIA DO PETRÓLEO

Laura Gabriela Gurgel de Carvalho

Bruna Luiza Batista de Lima

Nívia do Nascimento Marques

Marcos Antonio Villetti

Men de Sá Moreira de Souza Filho

Rosângela de Carvalho Balaban

DOI 10.22533/at.ed.8422017091

CAPÍTULO 2..... 12

ANÁLISE DE COMBUSTÍVEIS (GASOLINA COMUM) POR MÉTODOS ELETROANALÍTICOS EM MEIO MICROEMULSIONADO COMERCIALIZADOS NA CIDADE DE SÃO LUÍS - MA

Lorena Carvalho Martiniano de Azevedo

Leila Maria Santos da Silva

Deracilde Santana da Silva Viégas

Érico June Neves Texeira

Natália Tamires Gaspar Sousa

Aldaléa Lopes Brandes Marques

DOI 10.22533/at.ed.8422017092

CAPÍTULO 3..... 27

ANÁLISE DOS PRODUTOS DE REAÇÃO DA CONDENSAÇÃO ENTRE 2-HIDRÓXI-ACETOFENONA E P-ANISALDEÍDO EM MEIO BÁSICO

Heriberto Rodrigues Bitencourt

Carlos Alberto Beckman de Albuquerque

Antonio Pedro da Silva Souza Filho

Maricelia Lopes dos Anjos

Carla Jacqueline de Almeida Maciel

Jeferson Rodrigo Souza Pina

José Ciriaco Pinheiro

Lady Laura Pantoja Pereira de Carvalho

Andrey Moacir do Rosário Marinho

Ossalín de Almeida

DOI 10.22533/at.ed.8422017093

CAPÍTULO 4..... 35

ANÁLISE TÉRMICA DO POLI (ÁCIDO LÁTICO) COM AGENTES NUCLEANTES: TALCO, PET MICRONIZADO E ARGILA MONTMORILONITA

Alex Melo da Silva

Anderson Maia

Rondes Ferreira da Silva Torin

DOI 10.22533/at.ed.8422017094

CAPÍTULO 5..... 41

APLICAÇÃO DA CFD NO ESTUDO DO EFEITO DO DIÂMETRO DE GOTAS E DO NÍVEL DE ÁGUA NA SEPARAÇÃO GRAVITACIONAL ÁGUA-ÓLEO

Vinícius Gomes Morgan
Daniel da Cunha Ribeiro
Ana Paula Meneguelo
Lucas Henrique Pagoto Deoclecio
Wenna Raissa dos Santos Cruz
Luciana Spinelli Ferreira

DOI 10.22533/at.ed.8422017095

CAPÍTULO 6..... 48

AROMATERAPIA COM ÓLEO YLANG-YLANG (*Cananga odorata*) E PERCEPÇÃO DE BEM-ESTAR EM MULHERES CLIMATÉRICAS

Edna Maria Lemos e Silva Gualberto
Maria da Conceição Ferreira Baia
Claudia Chagas de Pontes
Roseane Rodrigues Siqueira

DOI 10.22533/at.ed.8422017096

CAPÍTULO 7..... 58

DESCOLORAÇÃO FÚNGICA DE CORANTES TÊXTEIS

Mayara Thamela Pessoa Paiva
Fabiana Guillen Moreira Gasparin
Suely Mayumi Obara Doi

DOI 10.22533/at.ed.8422017097

CAPÍTULO 8..... 76

ESTUDO DAS CONDIÇÕES DE PREPARO DO BAGAÇO DE MALTE DE CERVEJARIA NA OBTENÇÃO DE GLICOSE APÓS SUA HIDRÓLISE ÁCIDA

Fernanda Ferreira Freitas
Margarete Martins Pereira Ferreira
Araceli Aparecida Seolatto
Danielle Pires Nogueira
Rodrigo Silva Fontoura

DOI 10.22533/at.ed.8422017098

CAPÍTULO 9..... 89

ESTUDO DA DISTRIBUIÇÃO DO TEMPO DE RESIDÊNCIA EM UM REATOR CONTÍNUO DE TANQUE AGITADO

Thalles de Assis Cardoso Gonçalves
Mayara Mendes Costa
Mariana Oliveira Marques
Hugo Lopes Ferreira
Robson Antônio de Vasconcelos
Vitor Hugo Endlich Fernandes
Mário Luiz Pereira Souza

DOI 10.22533/at.ed.8422017099

CAPÍTULO 10..... 96

ESTUDO DA ESTABILIDADE OXIDATIVA DO ÓLEO DE MARACUJÁ (*PASSIFLORA EDULIS*) UTILIZANDO O MÉTODO PETROOXY (ASTMD 7545)

Yguatyara de Luna Machado

Natalia Freitas Oliveira

DOI 10.22533/at.ed.84220170910

CAPÍTULO 11 104

ESTUDO DO COMPORTAMENTO DA GOMA DE LINHAÇA EM MEIO AQUOSO POR ESPALHAMENTO DE LUZ DINÂMICO E REOLOGIA

Laura Gabriela Gurgel de Carvalho

Nívia do Nascimento Marques

Mariana Alves Leite Dutra

Marcos Antonio Villetti

Rosangela de Carvalho Balaban

DOI 10.22533/at.ed.84220170911

CAPÍTULO 12.....113

ESTUDO FITOQUÍMICO, MORFOLÓGICO E AVALIAÇÃO DO EXTRATO ETANÓLICO, DAS FOLHAS DO PAU MOCÓ (*Luetzelburgia auriculata*), QUANTO ÀS ATIVIDADES CONTRA AGENTES VETORIAIS E ANTIOXIDANTE

Antônio Marcelo Alves Lima

Eveline Solon Barreira Cavalcanti

André Castro Carneiro

Lara Pinheiro Xavier

Henety Nascimento Pinheiro

Brício Thiago Pinheiro

DOI 10.22533/at.ed.84220170912

CAPÍTULO 13..... 123

EXPRESSÃO DIFERENCIAL DA SUPERÓXIDO DISMUTASE E CATALASE DURANTE A GERMINAÇÃO DE *Lactuca sativa* L. EXPOSTA A METAIS PESADOS

Antonio Rodrigues da Cunha Neto

Marília Carvalho

Kamilla Pacheco Govêa

Giselle Márcia de Melo

Marília Mendes dos Santos Guaraldo

Heloisa Oliveira dos Santos

Sandro Barbosa

DOI 10.22533/at.ed.84220170913

CAPÍTULO 14..... 134

INCORPORAÇÃO DA ETAPA DE PRÉ-HIDRÓLISE ÁCIDA NO PROCESSO DE OBTENÇÃO DE NANOLÍTER

Danielle Goveia

Vinicius de Jesus Carvalho de Souza

Estefânia Vangelie Ramos Campos

Jose Claudio Caraschi

DOI 10.22533/at.ed.84220170914

CAPÍTULO 15..... 145

MICROENCAPSULAÇÃO DE ÓLEO DE PEQUI (*Caryocar coriaceum*) EM MATRIZ DE ALGINATO/QUITOSANA POR GELIFICAÇÃO IÔNICA: AVALIAÇÃO DA VISCOSIDADE NA MORFOLOGIA DAS PARTÍCULAS

Herllan Vieira de Almeida

Rachel Menezes Castelo

Luana Carvalho da Silva

Maria Leônia da Costa Gonzaga

Pablyana Leila Rodrigues da Cunha

Roselayne Ferro Furtado

DOI 10.22533/at.ed.84220170915

CAPÍTULO 16..... 155

MODELAGEM CINÉTICA DA DESCOLORAÇÃO DO CORANTE CROMOTROPE 2R POR PROCESSOS FENTON MEDIADOS POR FENÓIS DERIVADOS DE LIGNINA

Cássia Sidney Santana

Camila Cristina Vieira Velloso

André Aguiar

DOI 10.22533/at.ed.84220170916

CAPÍTULO 17..... 162

ÓLEO ESSENCIAL DE CAPIM LIMÃO: ESTRATÉGIA PARA A PROTEÇÃO DE SEMENTES E GRÃOS VISANDO A AGRICULTURA ORGÂNICA

Marcela de Souza Alves

Elisabeth Alves Duarte Pereira

Erica Prilips Esposito

Ana Flávia Carvalho da Silva

Emerson Guedes Pontes

Marco Andre Alves de Souza

DOI 10.22533/at.ed.84220170917

CAPÍTULO 18..... 174

OPTIMIZATION SYNTHESIS OF BIODIESEL FROM MACAUBA OIL (*ACROCOMIA ACULEATA*) USING EXPERIMENTAL DESIGN TECHNIQUE

Michelle Budke Costa

Maikon Aparecido Schulz dos Santos

Eduardo Eyng

Juliana Cortez

Daniel Walker Tondo

Laercio Mantovani Frare

Melissa Budke Rodrigues

DOI 10.22533/at.ed.84220170918

CAPÍTULO 19.....	191
PRÉ-TRATAMENTO ÁCIDO EM RAMAS DE MANDIOCA VISANDO PRODUÇÃO DE ETANOL SEGUNDA GERAÇÃO	
Ana Luiza Alves Faria	
Raphael Sarraf Martins Torraca	
Emilia Savioli Lopes	
Jaqueline Costa Martins	
Milena Savioli Lopes	
Melina Savioli Lopes	
DOI 10.22533/at.ed.84220170919	
CAPÍTULO 20.....	197
TEORIA DO ESTADO DE TRANSIÇÃO: DIHYDROAZULENE/VINYLSHEPTAFULVENE	
Andreas Erbs Hillers-Bendtsen	
Magnus Bukhave Johansen	
Kurt V. Mikkelsen	
DOI 10.22533/at.ed.84220170920	
SOBRE A ORGANIZADORA.....	203
ÍNDICE REMISSIVO.....	204

OPTIMIZATION SYNTHESIS OF BIODIESEL FROM MACAUBA OIL (*ACROCOMIA ACULEATA*) USING EXPERIMENTAL DESIGN TECHNIQUE

Data de aceite: 01/09/2020

Data de submissão: 19/08/2020

Michelle Budke Costa

Universidade Tecnológica Federal do Paraná
Medianeira-PR
<http://lattes.cnpq.br/8752647892614261>

Maikon Aparecido Schulz dos Santos

Universidade Tecnológica Federal do Paraná
Medianeira-PR
<http://lattes.cnpq.br/2138955298063724>

Eduardo Eyng

Universidade Tecnológica Federal do Paraná
Medianeira-PR
<http://lattes.cnpq.br/1101075438495044>

Juliana Cortez

Universidade Tecnológica Federal do Paraná
Cornélio Procópio-PR
<http://lattes.cnpq.br/9521479418175418>

Daniel Walker Tondo

Universidade Tecnológica Federal do Paraná
Medianeira-PR
<http://lattes.cnpq.br/7121442162301693>

Laercio Mantovani Frare

Universidade Tecnológica Federal do Paraná
Medianeira-PR
<http://lattes.cnpq.br/7676033878331606>

Melissa Budke Rodrigues

Universidade Tecnológica Federal do Paraná
Medianeira-PR
<http://lattes.cnpq.br/5087148127700008>

ABSTRACT: This study aimed to evaluate the synthesis of methyl esters, having as raw material macauba almond oil (*Acrocomia aculeata mart.*) from the transesterification reaction using p-toluenesulfonic acid as catalyst. The planning conducted for the transesterification trials was the Rotatable Central Composite Design, with a factor 2^2 , which originated the experimental mathematical model. The evaluation of the content of methyl esters was performed by thermogravimetry, and the best condition found for the percentage yield of methyl esters was obtained employing 11,5% catalyst, molar ratio of oil: methanol 1:6, 65°C temperature, 200 rpm stirring and reaction time of 4.25 hours, achieving a yield of 99%. From the generated mathematical model was demonstrated the validity of the experimental conditions.

KEYWORDS: Biofuel, Oil Macaúba almond, Transesterification, Thermogravimetry, Mathematical Model.

RESUMO: Este estudo teve como objetivo avaliar a síntese de ésteres metílicos, tendo como matéria-prima o óleo da amêndoa de macaúba (*Acrocomia aculeata mart.*), a partir da reação de transesterificação empregando o ácido p-toluenossulfônico. O planejamento realizado para os ensaios de transesterificação foi o Delineamento do Composto Central com fatorial de 2^2 sendo a avaliação do teor de ésteres metílicos obtida por termogravimetria. A melhor condição encontrada foi obtida empregando-se 11,5% de catalisador, razão molar óleo:metanol de 1:6, temperatura 65 °C, agitação de 200 rpm e tempo de reação de 4,25 horas, obtendo-se um

rendimento de 99%. A partir do modelo matemático gerado, foi comprovada a validade deste para as condições experimentais.

PALAVRAS-CHAVE: Biocombustível, Óleo da Amêndoa de Macaúba, Transesterificação, Termogravimetria, Modelo Matemático.

1 | INTRODUCTION

World politics has given relevance to new technologies that work together to build an ecologically sustainable and less polluted world. Due to limited oil reserves and the consequent increase in oil prices, renewable energy sources, biofuel, has been the subject of intense investigations¹⁻⁵.

A major advantage of the use of renewable energy sources (particularly those of vegetable origin) is in the fact of producing less polluting compounds^{6,7} and lower environmental impact in their burning processes, besides being part of the carbon mass naturally processed by plants.

Among the main renewable fuels stand out ethanol, vegetable oils and biodiesel⁸. The use of vegetable oils for biodiesel production, from the transesterification process has been object of recent research, attracting huge worldwide attention as an alternative fuel. Thus, the exploitation of native oilseeds need specific research to their encompassing in the energy matrix in a sustainable way^{5,9,10}.

In this context, the fruit of macauba palm (*Acrocomia aculeata mart.*) appears as a promising raw material for obtaining vegetable oils, mainly due to their high oil content in the pulp (60% to 70% on a dry basis) and in the nuts (40% to 50% on a dry basis), besides its high productivity (about 6.5 tons of oil per hectare)¹¹⁻¹⁴ economically important species of palm tree found in the Brazilian state of Mato Grosso do Sul. In this work, the general physicochemical characteristics and fatty acid composition of the fruit (boca\u00fava. It features wide dispersion in Brazil and neighboring countries such as Colombia, Bolivia and Paraguay. In Brazil, this palm is native in Minas Gerais, Ceará, Mato Grosso and Mato Grosso do Sul, being more abundant in the Cerrado region, where their exploitation is carried out in an extractive way, taking advantage of the occurrence of large populations in these regions¹⁴.

There are several studies on the use of macauba as raw material in the manufacture of oil for food purposes, the manufacture of soaps and burning for lighting and heating purposes. This palmácea excels in producing biodiesel for its oil production potential per unit area, adaptation (benefiting disadvantaged regions to commercial agriculture), plus the ability to use in agrossilvipastoris systems and viability in small plantations or associated with familiar agriculture^{15,16}.

The main way to obtain biodiesel is via transesterification reaction between a triglyceride, from vegetable oil, alcohol and a catalyst under appropriate conditions

of temperature and agitation. The reaction is processed in the presence of a catalyst and generates methyl/ethyl esters (biodiesel) and glycerol by-product, commonly called glycerin¹⁷⁻¹⁹.

Currently, the production of biodiesel is performed by transesterification of vegetable oil triglycerides using methanol and an alkali catalyst, usually NaOH or KOH²⁰⁻²² alkaline bases are used to catalyze the reaction. These catalysts require anhydrous conditions and feedstocks with low levels of free fatty acids (FFAs). The reaction is usually carried out at 60-80 °C and the glycerol and methyl ester are separated by sedimentation after neutralization of the catalyst^{23,24}.

The catalysts used are given special attention for its potential reduction of time and production costs, besides direct influence in the final product purity level²⁵⁻²⁷. In this context, p-toluenesulfonic acid (APTS) is a strong non-oxidizing acid having desirable characteristics for use as catalyst in transesterification processes. Due to peculiar features, this catalyst has highlighted as a catalyst in organic reactions. However, few studies in the literature report the utilization of APTS as catalyst for transesterification²⁸⁻³⁰. The research employing the APTS use a product with high purity. Sulfonac ATS 95 (p-toluenesulfonic acid 95%) is a product marketed in Brazil having wide applicability as catalyst in industrial processes. Its cost is about 3 to 4% of the p-toluenesulfonic acid 98% commercialized for chemical companies.

Within this context, the aim of this study is to evaluate the synthesis of methyl esters derived from macauba almond oil from the transesterification reaction employing the Sulfonac ATS 95 (p-toluenesulfonic acid) as a catalyst.

2 | MATERIALS AND METHODS

2.1 Materials and Reagents

The macauba almond oil was purchased from Cooperativa Central do Cerrado. The used catalyst, p-toluenesulfonic acid 95% (Sulfonac ATS 95), was supplied by Sisterquímica S/A. Methyl alcohol 99.8% was obtained from Alphatec. All reagents were utilized without previous physical-chemical treatment.

2.2 Transesterification Reaction of oil

On a 250 mL volumetric flask attached to a reflux condenser, 10g of oil was added until reaching the reaction temperature (65°C). The catalyst solution and methyl alcohol was separately prepared and added to the preheated oil. The computation time started with the sealing of the balloon and initiation of constant stirring (200 rpm). The amounts of catalyst and reaction time employees obeyed the predetermined experimental design. After the reaction period, the flask contents were transferred to a separatory funnel. The bottom layer containing glycerol and

impurities was drained. The top layer underwent a washing process using 40 mL (2 x 20 mL) of distilled water at 50°C. Subsequent to washing, the samples were heated for 30 minutes to remove any traces of water and methanol. The samples obtained in this process were stored in amber vials at room temperature (25°C).

2.3 Analytical Methodology

2.3.1 Analysis of fatty acid methyl esters

For determination of the fatty acid methyl esters profile, the lipids were by Hartman and Lago method (1973). The fatty acid methyl esters were analyzed on gas chromatograph (Perkin Elmer 680, USA) equipped with a flame ionization detector (FID) and fused silica capillary column (30 m x 0.25 mm x 0.25 μ m, Elite Wax, Varian). The column temperature was programmed to started with 65 °C, heating rate 15°C min⁻¹ up to 170°C, followed by heating rate 6°C min⁻¹ up 220°C. The sample split ratio used was 50:1 and sample volumes of 1 mL were injected. Ultrapure helium (White Martins), 1.30 mL min⁻¹, was used. The detector and injector temperatures were maintained at 220 °C and 230 °C, respectively. The fatty acids were identified by comparison of the retention times with those of fatty acid methyl ester standard (Supelco 23, Sigma–Aldrich).

2.3.2 Characterization of the almond oil and methyl ester

Macauba almond oil was characterized by acidity index (AOCS, 1998³⁰), peroxide index (AOCS, 1998³⁰), iodine index (AOCS, 1997³²), humidity (AOCS, 1997³²), density and viscosity measurements. Viscosity measurements were obtained using a basic rheometer (Brookfield DV-III) at 25° C temperature with rotational speed 100 rpm. The density was calculated using a 25mL pycnometer at 20 ° C temperature.

The amount of methyl esters present in transesterified samples of macauba almond oil was estimated using thermogravimetric analysis performed on a PerkinElmer thermo analyzer, model STA 6000, expressed as a weight loss percentage. The employed experimental condition for thermogravimetric analysis was heating about 6 mg of sample from 50°C to 600°C, with 10°C min⁻¹ heating rate in nitrogen atmosphere with a flow of 20 mL min⁻¹ using a platinum sampler.

Furthermore, the functional groups of biodiesel samples were investigated using absorption spectroscopy in the infrared - FTIR, acting in the range between 4000 cm⁻¹ and 400 cm⁻¹ with resolution of 2 cm⁻¹ and number of accumulations of 16 spectra. A FTIR Perkin Spectrum100 spectrophotometer was used in order to obtain the spectrum samples in attenuated total reflectance UATR mode.

2.4 Experimental Planning

A Rotatable Central Composite Design (RCCD) was used, based on Response Surface Methodology. The independent variables were the concentration of APTS and time. The dependent variable was the concentration of methyl esters defined by thermogravimetric analysis.

For the RCCD experimental design 2^2 factorial trials were performed with 5 repetitions at the central point and 4 trials in the axial points, totaling 13 trials. Statistical tests were performed by Statistic 7.0 statistical software, where the main effects of the factors and their interactions on the response variable were calculated. The molar ratio of oil:methanol 1:6, 65°C temperature and agitation of 200 rpm were set.

In Table 1, the conditions provided can be seen as well as the intervals of the study design variables. The choice of these experimental groups was based on results from preliminary tests.

	-1.41	-1	0	1	+1.41
Time (h)	1.59	2	3	4	4.41
Catalyst (%)	6.6	8	11.5	15	16.4

Table 1. Real values corresponding to the coded

A quadratic model was fitted to fatty acid methyl ester concentration (FAME) response due to the factors: reaction time and catalyst concentration, according to Equation 1.

$$CEM = \alpha_1 + \alpha_2 t^2 + \alpha_3 t + \alpha_4 C^2 + \alpha_5 C + \alpha_6 t.C \quad (\text{Equation 1})$$

Where:

FAME = Fatty Acid Methyl Ester (%);

α_i = Model regression coefficients.

t = Reaction time (encoded value, dimensionless).

C = Catalyst Concentration (encoded value, dimensionless).

3 | RESULTS AND DISCUSSION

A. Characterization of the almond oil

The values of acidity index, peroxide index, iodine index, humidity, density and viscosity are given in Table 2. These analyzes indicate that the oil used in this

study has suitable characteristics for biodiesel production. The acid index value was higher than expected, however, there are several factors that influence the oil acidity, such as how the harvest is done, ripening, storage and realization of fruit drying processes, as well as forms of oil extraction. Thus, these factors may explain the different values for the acid value reported in the literature.

Analysis	Value
Acidity index (mgKOH g ⁻¹)	3.9 ± 0.25
Peroxide index (meqK g ⁻¹)	5.9 ± 0.21
Iodine index (gI ₂ /100)	26.69 ± 1.48
Density (gm L ⁻¹)	0.91 ± 0.01
Humidity (%)	0.22 ± 0.01
Viscosity (cSt)	40.66 ± 1.29

Table 2 - Characterization of the macauba almond oil

The fatty acid methyl esters profile of macauba almond oil consists of unsaturated and saturated fatty acids. Oleic acid is predominant, about 38.59%, 43.49% of the total unsaturated fatty acids as can be seen in Table 3.

Retention (min)	Fatty acid (%)	MM	Value Found (%)
14.973	Lauric acid (C12:0)	200.32	27.9
19.423	Myristic acid (C14:0)	228.37	10.77
25.640	Palmitic acid (C16:0)	256.43	10.65
30.163	Stearic Acid (C18:0)	284.48	5.47
30.666	Oleic acid (C18:1n-9)	282.46	38.59
31.501	Linoleic acid (C18:2n-6)	288.44	4.12
	Outros		2.50

Table 3 - Fatty acid composition of macauba almond oil sample.

B. Thermogravimetric Analysis applied to biodiesel

The transesterification reactions of the macauba almond oil were performed using variable concentration of APTS and time, the molar ratio oil:methanol 1:6, 65°C temperature and constant stirring of 200 rpm defined using literature searches and preliminary testing. To set the response variable, concentration of methyl esters, thermogravimetric analysis was employed for the monitoring of transesterification reactions and observation of thermodegradation stages of biodiesel and oil ³¹.

Thus, based on thermodegradation temperature range for macauba almond oil and its methyl esters and in the identification of bands present in the thermogravimetric profile of the sample it was possible to determine the percentage conversion of the biodiesel produced.

In Table 4, it is possible to view the conditions provided by the experimental design for execution of the reactions as well as the percentage concentration of methyl esters, evaluated by thermogravimetric analysis (TGA).

Run	t (h)	C (%)	FAME (%)
1	4 (+1)	8 (-1)	91
2	2 (-1)	8 (-1)	80
3	4 (+1)	15 (+1)	98
4	2 (-1)	15 (+1)	93
5	3 (0)	11.5 (0)	94
6	3 (0)	11.5 (0)	93
7	3 (0)	11.5 (0)	94
8	3 (0)	11.5 (0)	95
9	3 (0)	11.5 (0)	93
10	4.25 (+1.41)	11.5 (0)	99
11	1.35 (-1.41)	11.5 (0)	88
12	3 (0)	16.4 (+1.41)	98
13	3 (0)	6.6 (-1.41)	79

Table 4. Results for the response variable, concentration of fatty acid methyl esters (FAME) for RCCD with a factor 2².

t: time; C: catalyst; FAME = Fatty acid methyl ester concentration;

It was found that the content of methyl esters had a variation of 79% to 99%, increasing with the increase in time and percentage of catalyst used in the testing and it was possible to achieve a minimum percentage of esters needed for the transesterified oil. Biodiesel can be considered, over 96.5%, as determined by the Agência Nacional de Petróleo, Gás Natural e Biocombustíveis - ANP, Brazil. ³².

The three best results (3, 10 and 12) ranged from 3 to 4.25h and 11.5 to 16.4% catalyst. It was observed that the amount of catalyst used was inversely proportional to the reaction time.

The best conditions found, where a transesterified ester content of 99% was obtained, was reached at an axial point, using 11.5% catalyst, 4.25 h reaction time, molar ratio oil:methanol 1:6, 200 rpm stirring and 65°C temperature.

Based on the levels of methyl esters obtained (93% to 95%) to the central points, trials 5 to 9 can confirm the repeatability of the tests.

The thermogravimetric profiles of macauba almond methyl biodiesel oil of tests 3, 10 and 13, where the highest and lowest yield were noted, along with the macauba almond oil are illustrated in Figure 1.

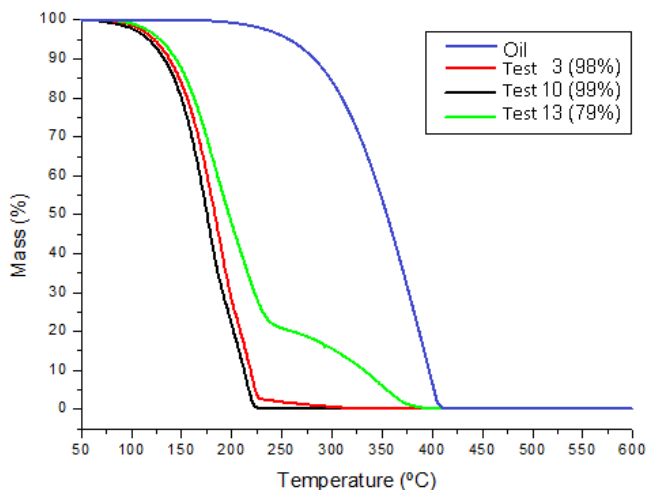


Figure 1. Thermogram of tests 3, 10 and 13.

For the analysis of the percentage of methyl esters obtained in the reaction was first performed the thermogravimetric profile of the oil, which showed a single degradation step (220 to 420°C), as can be seen in Figure 2. This parameter was used as a reference for other analyzes.

The curves for tests illustrate that biodiesel has two steps of volatilization. The larger mass losses thresholds that are observed until an approximate temperature of 225°C can be attributed to the methyl esters, the other step is associated with the carbonization of the sample.

In the spectrum of the methyl biodiesel of the macauba almond oil resulting from test 10 (Figure 2a), where the highest yield was obtained, absorption bands of the functional group C=O (carbonyl) can be verified, and an axial average absorption of the functional group C=O–C–O (ester) in the region of 1750 cm^{-1} to 1220 cm^{-1} respectively. The methylene groups $(\text{CH}_2)_n$ of the carbon chain of esters were confirmed by the bands in the region of 3000 cm^{-1} and 720 cm^{-1} .

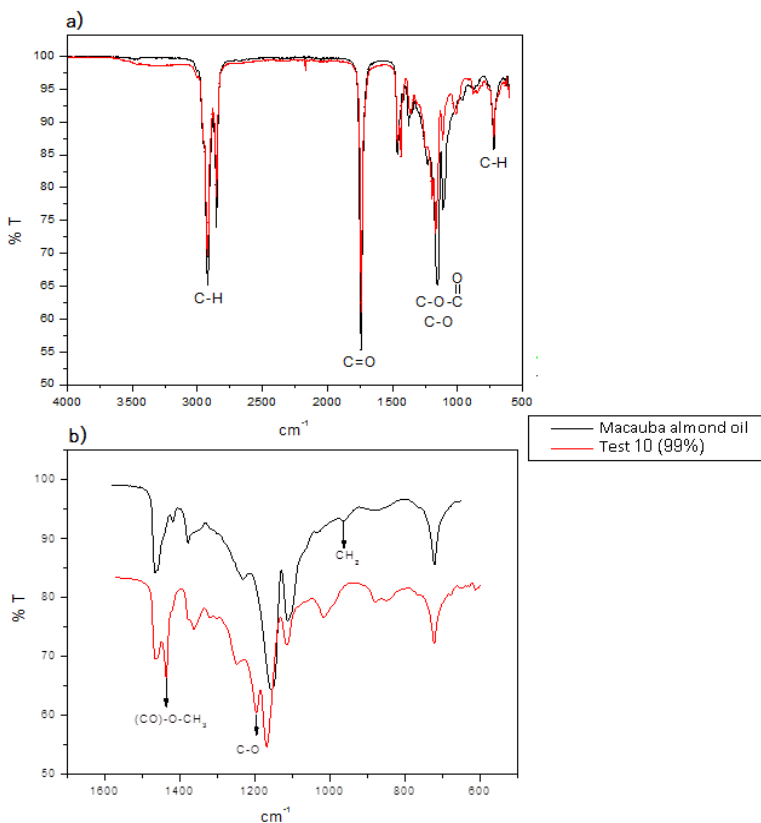


Figure 2. a) Infrared spectrum of biodiesel (99%) of test 10 and macauba almond oil. b) Absorption bands in region the 660 cm⁻¹ to 1600 cm⁻¹.

Comparing the spectrum of the methyl esters of the test 10 with the macauba almond oil (Figure 2b), it was possible to observe differences in displacements and in the intensity of absorption bands in region the 660 cm⁻¹ to 1600 cm⁻¹. In the region in 1168 cm⁻¹ which identifies one of the major changes present in methyl esters, this band in the oil appears as a strong signal at 1159 cm⁻¹ after transesterification this signal is divided into two on biodiesel, that they are visible in 1168 and 1195 cm⁻¹, the latter being equivalent to CO stretching band of an ester.

The region of 960 cm⁻¹ was observed in the oil, which relates to symmetric vibration out of the plane of this in CH₂ triglyceride and the band in 1435 cm⁻¹ in the biodiesel, which is related to deformation vibration of the methyl ester group.

C. Statistical Analysis and Validation of the Experimental Model

In Figure 3 is observed the Pareto diagram for the parameters studied. This

diagram allows you to check the effect of each parameter monitored, as well as which terms are statistically significant. Considering the 95% confidence interval, the quadratic term of the catalyst, the linear term of the catalyst and time, as well as the interaction between them, it was verified that were significant as the concentration of methyl esters.

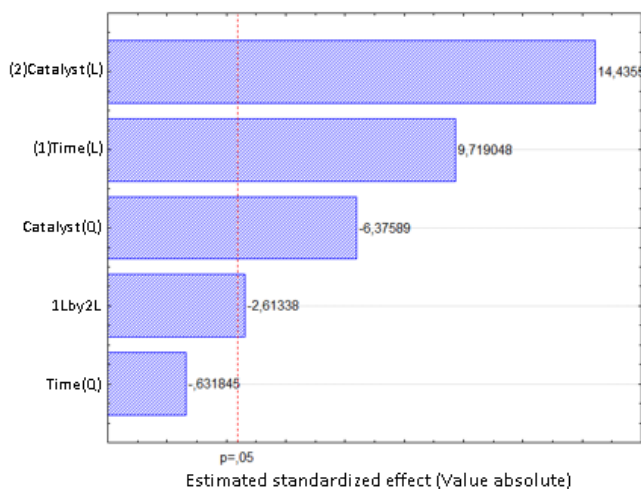


Figure 3. Pareto diagram for the yield content of esters, at a confidence level of 95%

Using the results obtained, the regression coefficients shown in Table 5 were calculated.

	Effects	Coefficients	Standard Error	p - value
Mean		93.8	0.5133	3.8824E-14
T	7.8890	3.9445	0.4058	2.5807E-05
I(t^2)	-0.55	-0.275	0.4352	0.5475
C	11.7175	5.8587	0.4058	1.8242E-06
I(C^2)	-5.55	-2.775	0.4352	0.0003
t:C	-3	-1.5	0.5739	0.0347

Table 5. Regression coefficients applied to the yield as a percentage of esters

t: time; C: catalyst

To perform the test of hypothesis (F test) and subsequent validation of the mathematical model is required to analyze the variance (ANOVA) for yield answer content of methyl esters, as can be seen in Table 6. This analysis model is the

most used to numerically evaluate the quality of the adjustment of a model, doing an analysis of waste. Despite the quadratic term of time not being significant in the range worked, it was decided to keep it in the mathematical model.

Source of Variation	Degrees of freedom	Sum of Squares	Mean Squares	F _{calculated}	F _{5; 7; 0.05} ^{tabulated}	p-value
Regression	5	461.699	92.340	70.013	3.972	7.9771E-06
Residual	7	9.224	1.318			
Total	12					

Table 6. Analysis of variance for the concentration-response esters (95% confidence interval)

According to Table 6 the value of F_{calculated} (70.013) is greater than F_{tabulated} (3.972) determining the validity of the model with 95% confidence, that can also be observed because the p-value is smaller than 0.05.

The quadratic model adjusted for the response Fatty Acid Methyl Ester Concentration (FAME) showed a coefficient of determination equal to 98.04%, confirming that the mathematical model satisfactorily explains the relation between the treatments used and observations.

From the model, it was possible to generate the surface response graphics and contour curves for the variable concentrations of methyl esters. In Figure 4 it is presented the response graphic in function of the variables time and percentage of catalyst.

The contour curves chart (Figure 5) shows a great region for the catalyst, approximately 0.1 to 1.2 in coded values, and a growing trend for the time, reaching 100% of the theoretical yield. However, in practice, because it is a reversible reaction, time values that exceed the range applied from 2 h to 4 h, can compromise the performance as a percentage of methyl esters.

The validation of the experimental model was performed under conditions of 0.3 (12.5%) for the catalyst and 1.2 (4.12h) for time in coded values. These conditions were established considering the optimal region provided by the surface response graph and contour curves, which propitiates values greater than those established by the Agência Nacional de Petróleo, Gás Natural e Biocombustíveis³³, in the matter of esters percentage, which is 96.5%, using reactants and the smallest possible power levels.

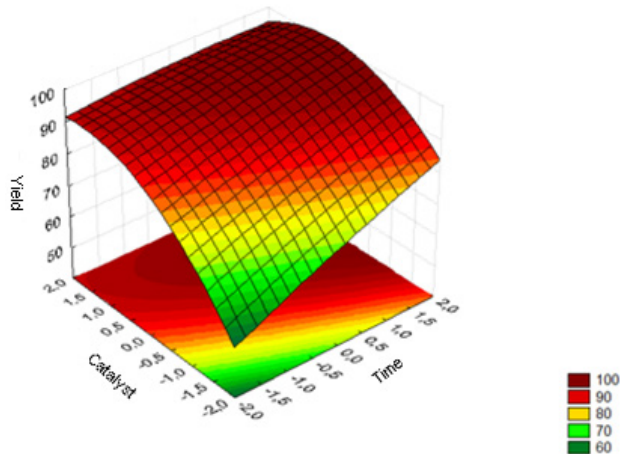


Figure 4. Surface response graph for the parameter concentration of esters in function of time and percentage of catalyst

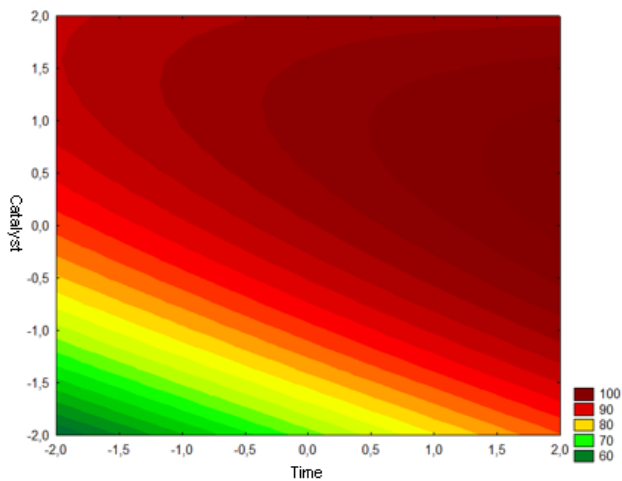


Figure 5. Graph contour curves for the concentration of esters parameter as a function of time and percentage of catalyst

Under such conditions, the value of the concentration of methyl esters predicted by the mathematical model was 99%. Thus, the model validated experimentally confirmed to obtain the esters, taking into account the optimal region obtained. In Table 7 there is the average of the concentrations achieved for validation tests.

Run	Time (h)	Catalyst (%)	FAME (%)
14	4.12 (1.2)	12.5 (0.3)	99
15	4.12 (1.2)	12.5 (0.3)	97
16	4.12 (1.2)	12.5 (0.3)	98
Mean			98

Table 7. Results of the validation of the experimental conditions, performed in triplicate, the temperature of 65°C, molar ratio oil:methanol 1:6 and 200 rpm stirring

In Figure 6, can be seen the thermogravimetric profiles of tests 14, 15 and 16, analyzed in an atmosphere of nitrogen.

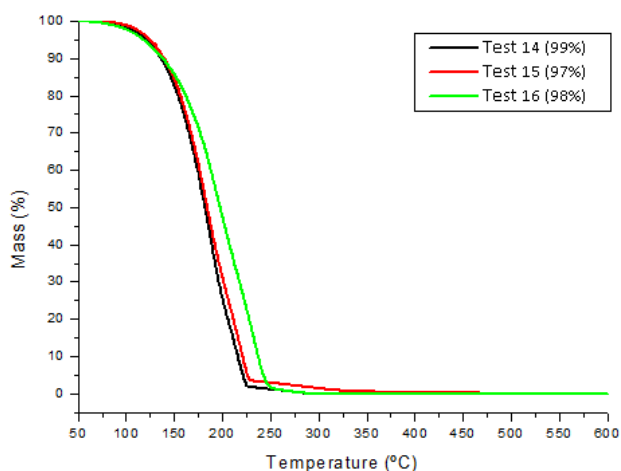


Figure 6. Thermogram of validation tests 39, 40 and 41 (C= 12.5%, R = 1:6 R and t = 4.12 h).

It can be seen that the concentration values of methyl esters found in validation tests ranged from 97% to 99%, which are very close values to the predicted by the model. Also, the average percentage error between the value predicted by the model for the selected condition and value observed in tests was validated by 1%, considered satisfactory value. Thus, it proved the validity of the mathematical model to the experimental conditions.

Because of the optimum range of weather conditions and catalyst percentage for the concentration of methyl esters above 96.5%, the analyzed conditions and reagents have great potential for industrial development, since small variations in the process do not result in major impacts on yield end.

A test was conducted without the presence of a catalyst employing the same

reaction conditions used in the test 10. However, it was not observed the formation of fatty acid methyl esters. The results obtained by some studies using macauba oil to obtain biodiesel are reported in Table 8. It is observed that the reaction conditions and catalysts employed have not exhibited superior results (except 37 reference employing more complex catalysts and higher amounts of solvent and temperature) that obtained with p-toluenesulfonic acid, which produced biodiesel with 99% FAME.

Catalyst (wt%)	Temperature (°C)	Time (min)	Oil:alcohol ratio	FAME (%)	Reference
Supercritical 15MPa	375	90	1:30 methanol (5wt% water)	78	34
Supercritical 15MPa	325	90	1:30 ethanol (5wt% water)	69.6	34
Sodium Methoxide (1)	Reflux	70	1:6 methanol	92.1	35
H ₂ SO ₄ (1.3)	113.9	120	1:10.3 ethanol	93.9	36
Nb ₂ O ₅ /SO ₄ (30)	250	240	1:120 ethanol	99.2	37
Supercritical 20MPa	325	45	1:50 methyl acetate	83	38
Enzyme CALB (6)	40% 5Hz (ultrasound)	30	1:6 methanol	93.3	39
Enzyme Novozym 435 (20)	65 ultrasound	30	1:9 ethanol	70	40
Enzyme Rhizomucor miehei (15.1)	40	480	1:3 ethanol	91	41

Table 8. Works using macauba oil for biodiesel production

The conditions employed in this work compared to other catalysts and systems employed in Table 8, it appears that the advantage of this process occur in a single step and cost of the catalyst (APTS 95 %) is very low, compared to the others catalysts.

Comparing this work to others that also used p-toluenesulfonic acid as catalyst, there is the lack of optimization studies applying this catalyst in transesterification reactions of vegetable oils to biodiesel production, furthermore all have employed APTS with high purity.

Reis *et al*²⁸ employed p-toluenesulfonic acid (homogeneous catalysis) in the esterification of free fatty acids as compared to A35 resin (heterogeneous catalysis), obtaining the best results for oleic and palmitic acids.

Encinar²⁹ diethyl ether (DEE, studied the application of p-toluenesulfonic acid in the pre-esterification of fats for later application basic catalysis. By applying just p-toluenesulfonic acid not obtained methyl ester yield.

It may be noted that the macauba almond oil has a great potential for biodiesel

production processes as well as the catalyst applied, p-toluenesulfonic acid 95%, in addition to even present a great economic viability because of its low cost of ownership compared to traditional catalysts applied as well as its pure compound.

4 | CONCLUSION

In the transesterification process of the macauba almond oil catalyzed by p-toluenesulfonic acid, the quantities were critical to high concentrations of methyl esters. For the applied planning, values equal or greater than 11.5% were needed for the yield, as the percentage of esters was higher than that required by the legislation of the Agência Nacional de Petróleo, Gás Natural e Biocombustíveis³³ to be considered biodiesel, which is 96.5%. Also, due to the acid character of the catalyst, it was found that reaction times of 2 hours are sufficient for the process to occur in its entirety.

Within the range applied in studying, the best condition found for the percentage yield of methyl esters was processed using 11.5% catalyst (p-toluenesulfonic acid) molar ratio oil:methanol 1:6, 65°C temperature, 200 rpm stirring and reaction time of 4.25 hours, achieving a yield of 99%;

Using the regression coefficients resulting of data of the experimental design, a mathematical model was generated. The validation of this was performed by means of an assay in triplicate, where it was observed an average percentage error of 1%, proving the validity of the mathematical model to the experimental conditions employed.

ACKNOWLEDGMENTS

The authors acknowledge the financial support given by CAPES and CNPq.

REFERENCES

- 1 M. Guo, W. Song, and J. Buhain, *Renew. Sustain. Energy Rev.* **42**, 712 (2015).
- 2 Brasil, *Minist. Da Agric. Pecuária E Abast.* 36 (2014).
- 3 L.P. Ramos, *Rev. Biotecnol. Ciência E Desenvol.* **31**, 229 (2003).
- 4 C.A.G. Garcez and J.N. de S. Vianna, *Energy* **34**, 645 (2009).
- 5 G.P.A.G. Pousa, A.L.F. Santos, and P.A.Z. Suarez, *Energy Policy* **35**, 5393 (2007).
- 6 A.C. Pinto, C. Zucco, F. Galembeck, J.B. de Andrade, and P.C. Vieira, *B2 - Quim. Nov.* **35**, 2092 (2012).

- 7 A.C. Pinto, L.L.N. Guarieiro, M.J.C. Rezende, N.M. Ribeiro, E. a. Torres, W. a. Lopes, P. a P. De Pereira, and J.B. De Andrade, *J. Braz. Chem. Soc.* **16**, 1313 (2005).
- 8 G. Knothe, *Fuel Process. Technol.* **86**, 1059 (2005).
- 9 F. Ma and M.A. Hanna, *Bioresour. Technol.* **70**, 1 (1999).
- 10 T. Issariyakul and A.K. Dalai, *Renew. Sustain. Energy Rev.* **31**, 446 (2014).
- 11 P.A. Hiane, M.M.R. Filho, M.I.L. Ramos, and M.L.R. Macedo, *Brazilian J. Food Technol.* **8**, 256 (2005).
- 12 A.O. Scariot, E. Lleras, and J.D. Hay, *Biotropica* **27**, 168 (1995).
- 13 A. da S. César, F. de A. Almeida, R.P. de Souza, G.C. Silva, and A.E. Atabani, *Renew. Sustain. Energy Rev.* **49**, 1213 (2015).
- 14 R. Ferrari and J.D.A. Filho, *J. Agric. Sci. Technol.* **2**, 1119 (2012).
- 15 E.C.G. Aguiaras, E.D. Cavalcanti-Oliveira, A.M. De Castro, M. a P. Langone, and D.M.G. Freire, *Fuel* **135**, 315 (2014).
- 16 F. Amaral, F. Broetto, C.B. Batistella, and S.M.A. Jorge, *Energ. Na Agric.* **26**, 12 (2011).
- 17 G.F. Ghesti, J.L. de Macedo, I.S. Resck, J.A. Dias, and S.C.L. Dias, *Energy and Fuels* **21**, 2475 (2007).
- 18 J.M. Marchetti, V.U. Miguel, and a. F. Errazu, *Renew. Sustain. Energy Rev.* **11**, 1300 (2007).
- 19 F. Dimas, B. Apolinário, and J.P. Ferreira, *Rev. Divulg. Do Proj. Univ. Petrobras E IF Flum.* **141** (2012).
- 20 E. Lotero, Y. Liu, D.E. Lopez, K. Suwannakarn, D. a. Bruce, and J.G. Goodwin, *Ind. Eng. Chem. Res.* **44**, 5353 (2005).
- 21 F. Ma and M.A. Hanna, *Bioresour. Technol.* **70**, 1 (1999).
- 22 A.C. Pinto, L.L.N. Guarieiro, M.J.C. Rezende, N.M. Ribeiro, E.A. Torres, W.A. Lopes, and J.B. De Andrade, *J. Braz. Chem. Soc.* **16**, 1313 (2005).
- 23 M. Di Serio, R. Tesser, L. Pengmei, and E. Santacesaria, *Energy & Fuels* **22**, 207 (2008).
- 24 Y.C. Sharma, B. Singh, and S.N. Upadhyay, *Fuel* **87**, 2355 (2008).
- 25 P. Lozano, *Green Chem.* **12**, 555 (2010).
- 26 M.J. Haas, *Fuel Process. Technol.* **86**, 1087 (2005).

- 27 R.B. Silva, A.F. Lima Neto, L.S.S. Santos, J.R. de O. Lima, M.H. Chaves, J.R. Santos, G.M. Lima, E.M. de Moura, and C.V.R. de Moura, *Bioresour. Technol.* **99**, 6793 (2008).
- 28 M.C. Reis, F.A. Freitas, E.R. Lachter, R.A.S.S. Gil, R.S.V. Nascimento, R.L. Poubel, and L. B.Borré, *Quim. Nova* **38(10)**, 1307 (2015).
- 29 J.M. Encinar, A. Pardal, and N. Sánchez, *Fuel* **166**, 51 (2016).
- 30 G. Guan, K. Kusakabe, N. Sakurai, and K. Moriyama, *Fuel* **88**, 81 (2009).
- 31 P. Chand, C.V. Reddy, J.G. Venkat, T. Wang, and D. Grewell, *Energy and Fuels* **23**, 989 (2009).
- 32 G.N. e B. Agência Natural do Petróleo, *Resolução ANP No 45, de 25.8.2014* (n.d.).
- 33 ANP, Agência Nac. Do Petróleo, Gás Nat. E Biocombustíveis (2014).
- 34 H.J. Navarro-Díaz, S.L. Gonzalez, B. Irigaray, I. Vieitez, I. Jachmanián, H. Hense, and J.V. Oliveira, *J. Supercrit. Fluids* **93**, 130 (2014).
- 35 L.N. Silva, C.C. Cardoso, and V.M.D. Pasa, *Fuel* **166**, 453 (2016).
- 36 G.K. Souza, F.B. Scheufele, T.L.B. Pasa, P.A. Arroyo, and N.C. Pereira, *Fuel* **165**, 360 (2016).
- 37 L.R. V da Conceição, L.M. Carneiro, J.D. Rivaldi, and H.F. de Castro, *Ind. Crops Prod.* **89**, 416 (2016).
- 38 G. Doná, L. Cardozo-Filho, C. Silva, and F. Castilhos, *Fuel Process. Technol.* **106**, 605 (2013).
- 39 P. Adewale, M.-J. Dumont, and M. Ngadi, *Chem. Eng. J.* **284**, 158 (2016).
- 40 S. Michelin, F.M. Penha, M.M. Sychoski, R.P. Scherer, H. Treichel, A. Valério, M. Di Luccio, D. de Oliveira, and J.V. Oliveira, *Renew. Energy* **76**, 388 (2015).
- 41 E.C.G. Aguiaras, E.D. Cavalcanti-Oliveira, A.M. De Castro, M. a P. Langone, and D.M.G. Freire, *Fuel* **135**, 315 (2014).

ÍNDICE REMISSIVO

A

- Agentes nucleantes 35, 39
- Alface 124, 126, 127, 131
- Alginato de sódio 145, 147, 152
- Amido de manga 1, 8, 10
- Análise de combustíveis 12, 13
- Armazenamento de energia térmica solar 197
- Aromaterapia 48, 50, 51, 56, 57
- Atividade antioxidante 28, 113, 115, 116, 118, 119, 121, 122, 146
- Atividade biológica 28, 162

B

- Bagaço de malte de cervejaria 76, 78
- Biofuel 174, 175

C

- Capim limão 162, 164, 165, 166, 168, 169, 170, 171
- Caracterização fitoquímica 113
- Chalcona 27, 29, 30, 32, 33
- Conversão 78, 89, 90, 156, 192
- Corante 58, 59, 61, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 91, 155, 156, 157, 158, 160, 161
- Corantes têxteis 58, 60, 71

D

- Descoloração fúngica 58
- Dispersão água-óleo 41, 46

E

- Enzimas antioxidantes 123, 125, 126, 127, 130, 132
- Estabilidade oxidativa 96, 102
- Etanol de segunda geração 78, 191, 192, 193

G

- Gelificação iônica 145, 146, 147, 152

Goma de linhaça 104, 105, 106, 108, 109, 110, 111

H

Hidrólise ácida 76, 78, 80, 81, 82, 86, 134, 136, 138, 139, 140, 142

L

Laurato de vinila 1, 3, 5, 6, 7, 8, 10

M

Mathematical model 174, 183, 184, 185, 186, 188

Metais pesados 13, 14, 123, 125, 126, 128, 129, 130, 131, 132

Métodos eletroanalíticos 12

Métodos Eletroanalíticos 12, 16

Microencapsulação 145, 152, 153

Modelagem cinética 155, 156, 160

Modificador reológico 1, 3, 5, 9, 10

Montmorilonita 35, 36

N

Nanocelulose 134, 135, 136, 137, 138, 142, 143, 144

O

Óleo de maracujá 96, 97, 98, 99, 100, 101, 102

Óleo de pequi 145, 147, 152

Óleo essencial 50, 51, 52, 53, 54, 162, 164, 165, 166, 167, 168, 169, 170, 171

Óleo ylang-ylang 48, 56

P

Pau-mocó 113, 114

Pet micronizado 35

Poli(ácido láctico) 35

Pré-hidrólise 134, 136, 138, 139, 140, 142

Pré-tratamento ácido 191, 192, 193, 195

Propriedades pro-oxidantes 155, 156, 160

R

Raio hidrodinâmico 104, 107, 109, 110, 111

Rama de mandioca 191

Reator CSTR 90

Reologia 104, 154

S





Separação gravitacional 41, 42, 43

Sistemas moleculares 197

T

Tempo de residência 89, 90, 91, 93, 94

A Química nas Áreas Natural, Tecnológica e Sustentável **3**

-  www.atenaeditora.com.br
-  contato@atenaeditora.com.br
-  [@atenaeditora](https://www.instagram.com/atenaeditora)
-  www.facebook.com/atenaeditora.com.br

A Química nas Áreas Natural, Tecnológica e Sustentável **3**

-  www.arenaeditora.com.br
-  contato@arenaeditora.com.br
-  [@arenaeditora](https://www.instagram.com/arenaeditora)
-  www.facebook.com/arenaeditora.com.br