FoRC
FOOD RESEARCH CENTER
Centro de Pesquisa em Alimentos

SIAN
Simpósio de Alimentos e Nutrição
17 E 18 DE JUNHO DE 2019

Bioeconomia e Alimentos: Uso de subprodutos ou resíduos na produção de novos materiais

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Introdução

Definição do Conselho Alemão de Bioeconomia, 2015: "Bioeconomia é a produção e utilização de recursos biológicos - incluindo o conhecimento - para fornecer produtos, processos e serviços em todos os setores dentro da estrutura de uma economia sustentável". (von Braun, 2018).

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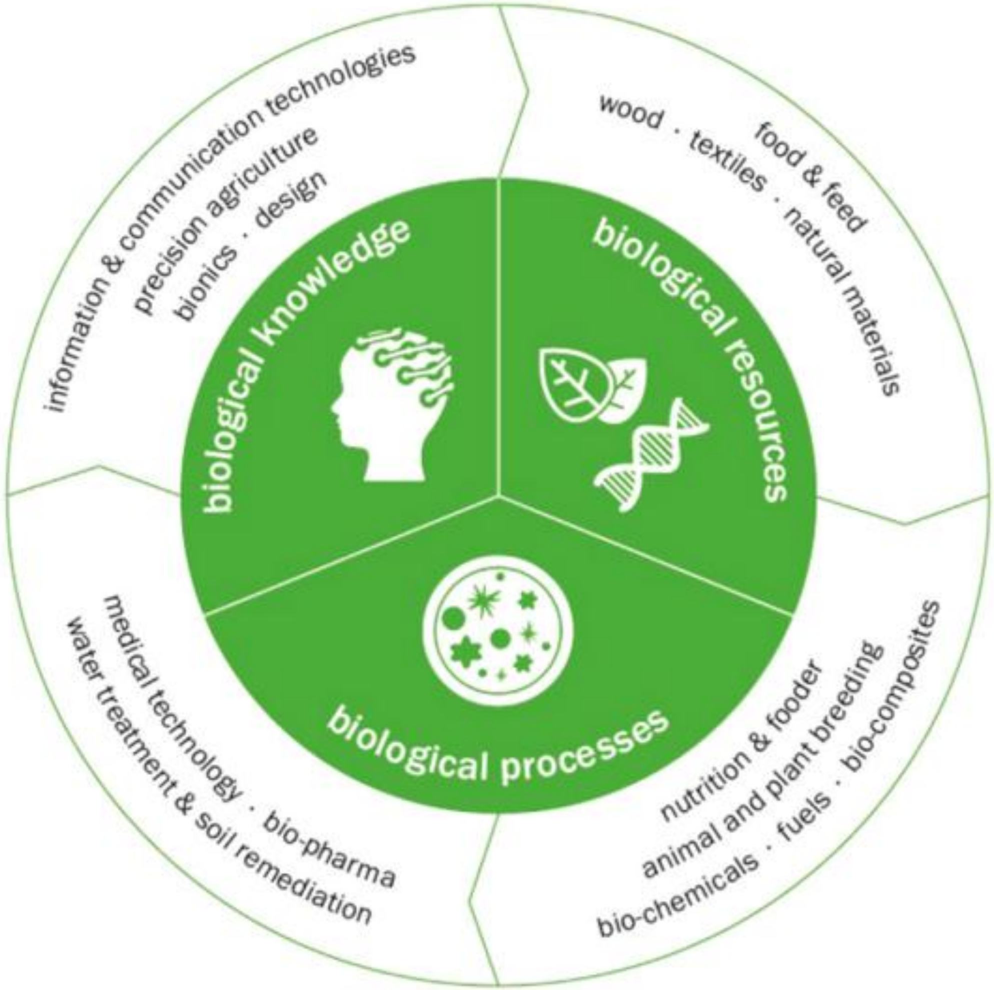


Fig. Bioeconomy Concept and Elements. Source: German Bioeconomy Council (2015).

Fonte: von Braun et al. (2018)

A bioeconomia compreende as partes da economia que usam recursos biológicos renováveis da terra e do mar de forma responsável, visando beneficiar as empresas, a sociedade e a natureza (McCormic & Kautto, 2013), a produção de alimentos sendo um desses usos (Kristinsson & Jörundsdóttir, 2019).

Mais de 2 biliões de euros em volume de negócios para a bioeconomia global na UE, que oferece mais de 18 milhões de empregos (Piotrowski et al., 2016).

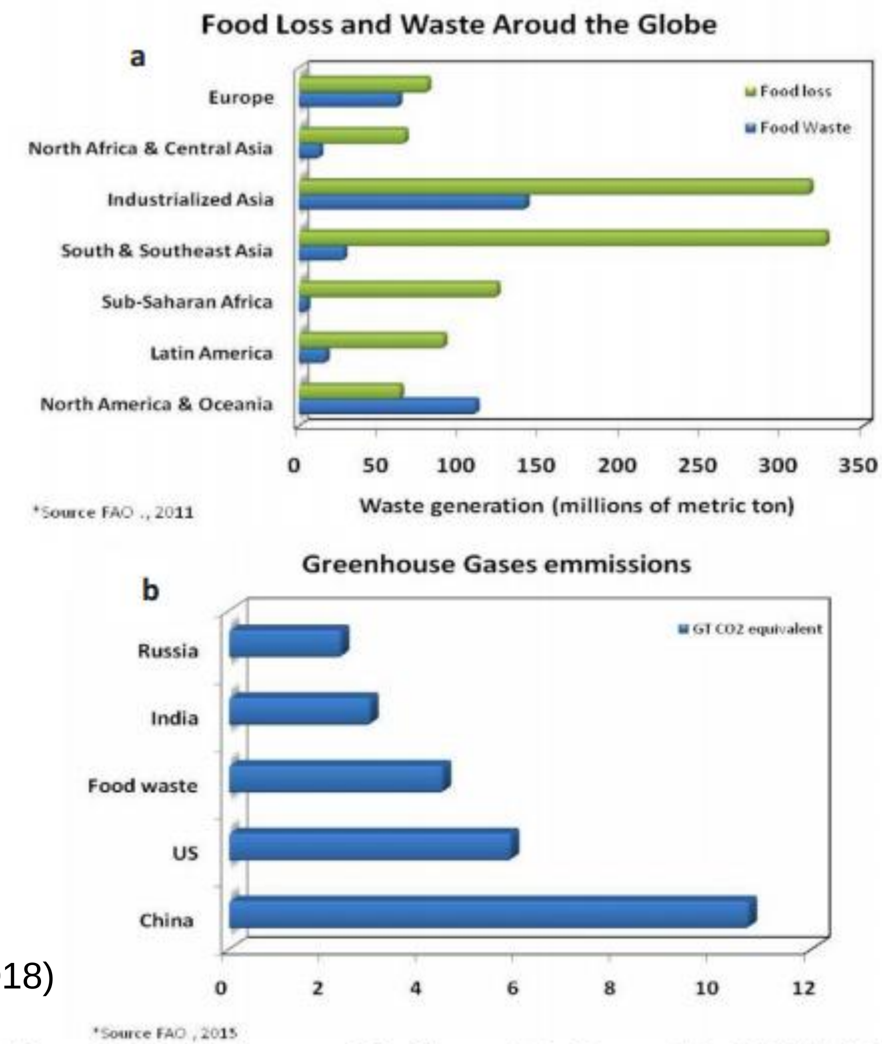
Até 2030, o mundo precisa produzir 50% a mais de alimentos, 45% a mais de energia e 30% a mais de água (WWAP, 2012).

Em um mundo que se aproxima de 9 bilhões de pessoas em meados do século 21, a necessidade de uma transformação do sistema econômico e do estilo de vida torna-se cada vez mais importante em direção à sustentabilidade (von Braun, 2018).

Nexus Água-Energia-Alimentos

Água, energia e alimentos são recursos essenciais e sistemas interdependentes. A necessidade de integração intersetorial da produção e provisão de recursos essenciais tem recebido maior atenção. Esta abordagem intersetorial é definida como o *Nexus* Água-Energia-Alimentos (Artioli et al., 2017).

A valorização de resíduos de alimentos é uma meta do desenvolvimento sustentável e ganha grande interesse, já que muitos produtos de base biológica podem ser derivados deles, além de energia e combustíveis (Rama Mohan, 2016).



Fonte: Dahiya et al. (2018)

Fig. (a) Global food waste and food loss statistics (Source: FAO, 2011) (b) Global green house gases emissions in terms of GT CO_2 equivalents (Source: FAO, 2015)

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Biorrefinarias

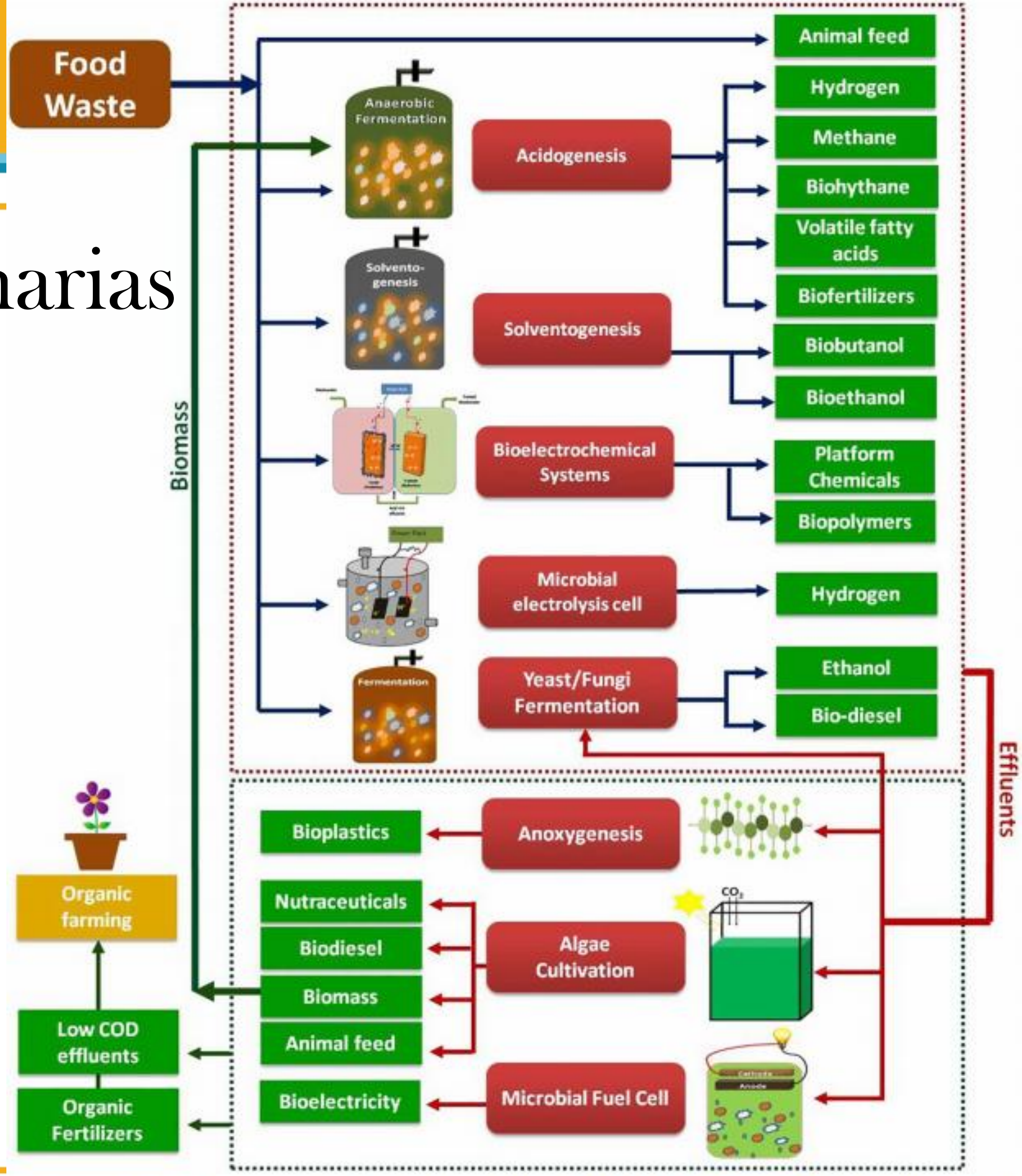
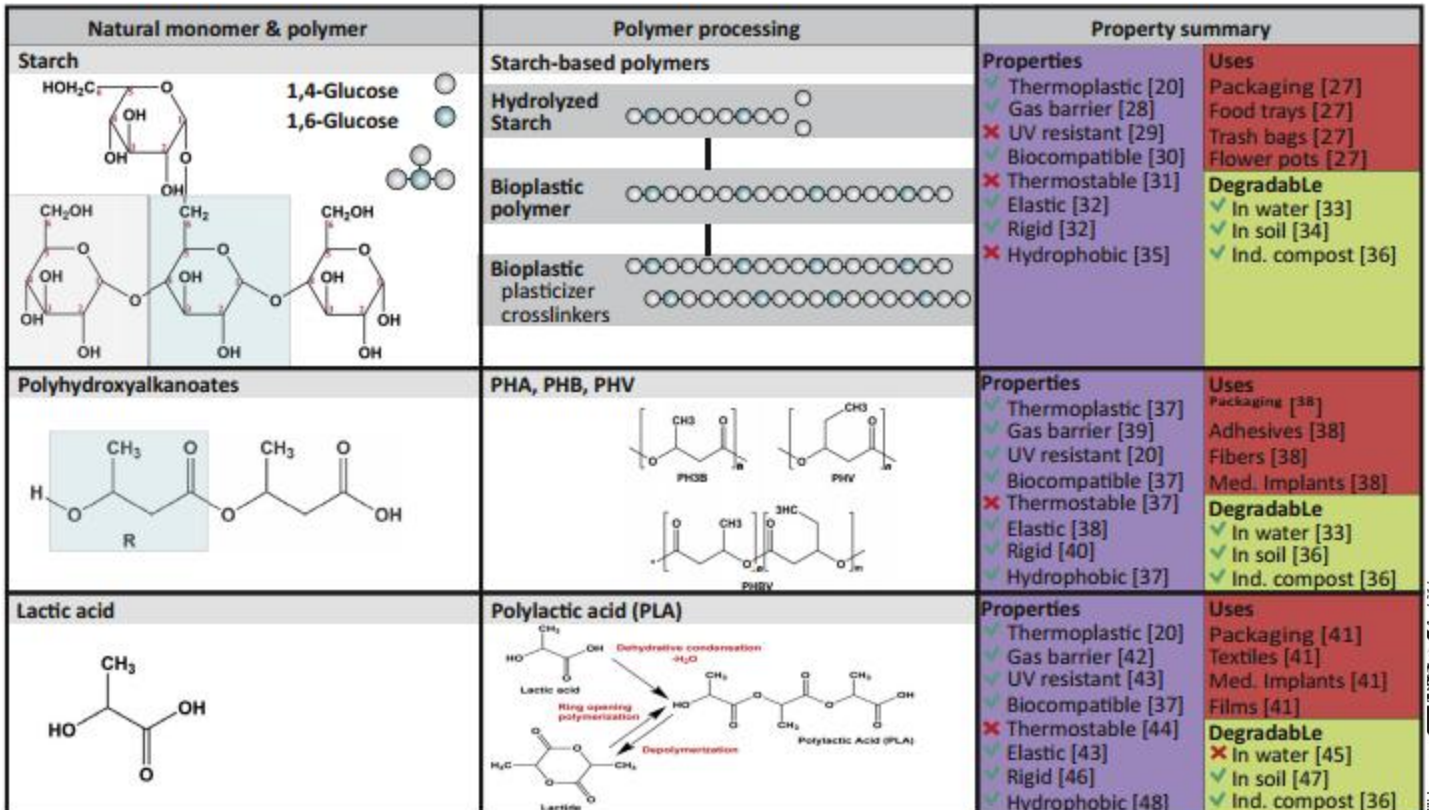


Fig. 5. Overview of multi-dimensional approaches for valorization of food waste to value added bio-based products in circular bioeconomy.

Fonte:
Dahiya et al. (2018)

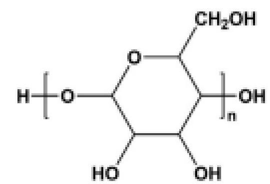
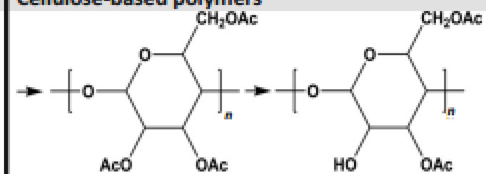
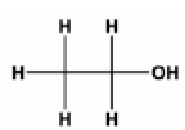
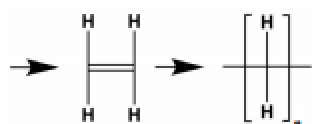
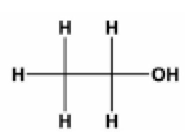
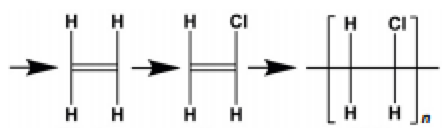
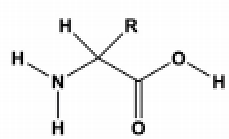
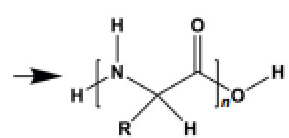
Figure Major Bioplastic Classes. Starch-based polymers, polyhydroxyalkanoates (PHAs) [including polyhydroxybutyrate (PHB), polyhydroxyvalerate (PHV), poly (3-hydroxybutyrate-co-3-hydroxyvalerate) (PHBV)], polylactic acid (PLA), cellulose-based polymers, polyethylene (PE), polyvinyl chloride (PVC), and protein-based polymers. Bioplastic input monomers and polymers (left-hand column), polymer production steps (middle column), properties, uses, and degradability characteristics (right-hand columns).



Fonte: Karan et al. (2019)

Continua...

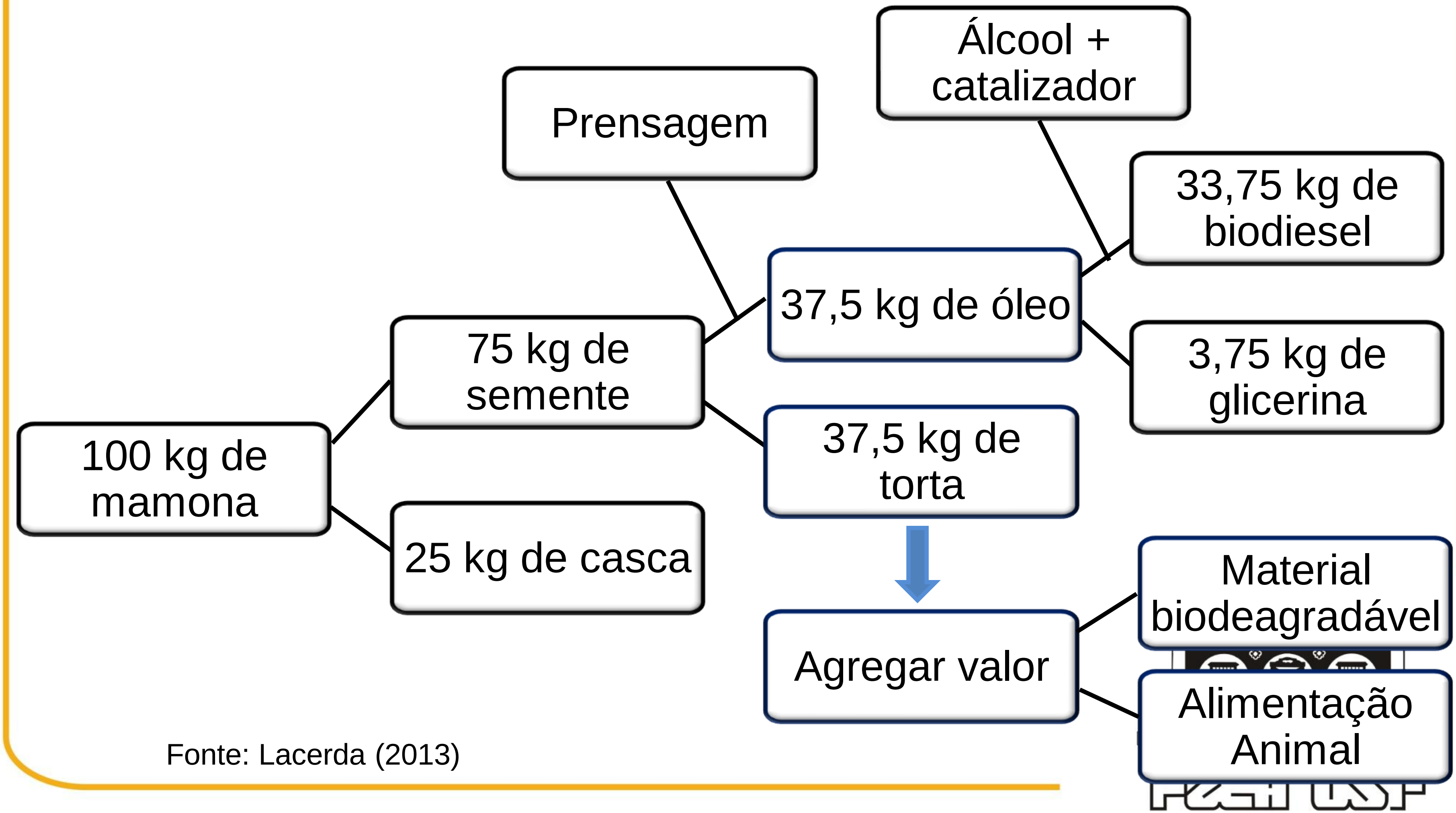
Figure Major Bioplastic Classes. Starch-based polymers, polyhydroxyalkanoates (PHAs) [including polyhydroxybutyrate (PHB), polyhydroxyvalerate (PHV), poly (3-hydroxybutyrate-co-3-hydroxyvalerate) (PHBV)], polylactic acid (PLA), cellulose-based polymers, polyethylene (PE), polyvinyl chloride (PVC), and protein-based polymers. Bioplastic input monomers and polymers (left-hand column), polymer production steps (middle column), properties, uses, and degradability characteristics (right-hand columns).

		Properties	
Cellulose 	**Cellulose-based polymers**  Cellulose triacetate · Cellulose acetate	**Properties** ✗ Thermoplastic [31] ✗ Gas barrier [49] ✗ UV resistant[viii] ✓ Biocompatible [50] ✓ Thermostable [51] ✗ Elastic [52] ✓ Rigid [54] ✗ Hydrophobic [54]	**Uses** Wound dress.[vii] Textiles[vii] Air filters[vii] Coatings[vii] **DegradabLe** ✓ In water [53] ✓ In soil [55] ✓ Ind. compost [36]
Ethanol 	**Polyethylene**  Ethylene · PE	**Properties** ✓ Thermoplastic [17] ✓ Gas barrier [57] ✗ UV resistant [58] ✓ Biocompatible[ix] ✗ Thermostable[x] ✓ Elastic[xi] ✓ Rigid[xii] ✓ Hydrophobic[xiii]	**Uses** Bottles [56] Ship container [56] Container lids [56] Adhesives [56] **DegradabLe** ✗ In water [11] ✗ In soil [34] ✗ Ind. compost [34]
Ethanol 	**Polyvinyl chloride**  Ethylene · Vinyl chloride · PVC	**Properties** ✓ Thermoplastic [17] ✗ Gas barrier [59] ✗ UV resistant[xiv] ✓ Biocompatible[ix] ✗ Thermostable [60] ✓ Elastic[xv] ✓ Rigid[xiv] ✓ Hydrophobic [62]	**Uses** Packaging [56] Window frames [56] Railings [56] Pipes [56] **Degradable** ✗ In water[xvi] ✗ In soil [61] ✗ Ind. compost [17]
Amino acid 	**Protein-based polymers** 	**Properties** ✓ Thermoplastic [63] ✗ Gas barrier [65] ✓ UV resistant [66] ✓ Biocompatible [67] ✓ Thermostable [68] ✓ Elastic [65] ✓ Rigid [70] ✓ Hydrophobic [71]	**Uses** Cast film [64] Injection mold. [64] Compr. mold. [64] Extrud. sheets [64] **DegradabLe** ✓ In water [69] ✓ In soil [69] ✓ Ind. compost [69]

Fonte: Karan et al. (2019)

Alguns Resultados – biopolímeros

Cadeia do biodiesel – torta de mamona



Fonte: Lacerda (2013)

Fluxograma de extração de proteína

Torta (20%)

Agitação (400 rpm, 50ºC)

Ajuste de pH

Extração (tempo reação 30')

Centrifugação (4.000 rpm)

- Proteínas (sobrenadante)
  - Liofilização
  - Extrato protéico liofilizado
  - Filmes

- Resíduo (decantado)
  - Secagem
  - Resíduo seco
  - Nutrição Animal

Fonte: Lacerda (2013)

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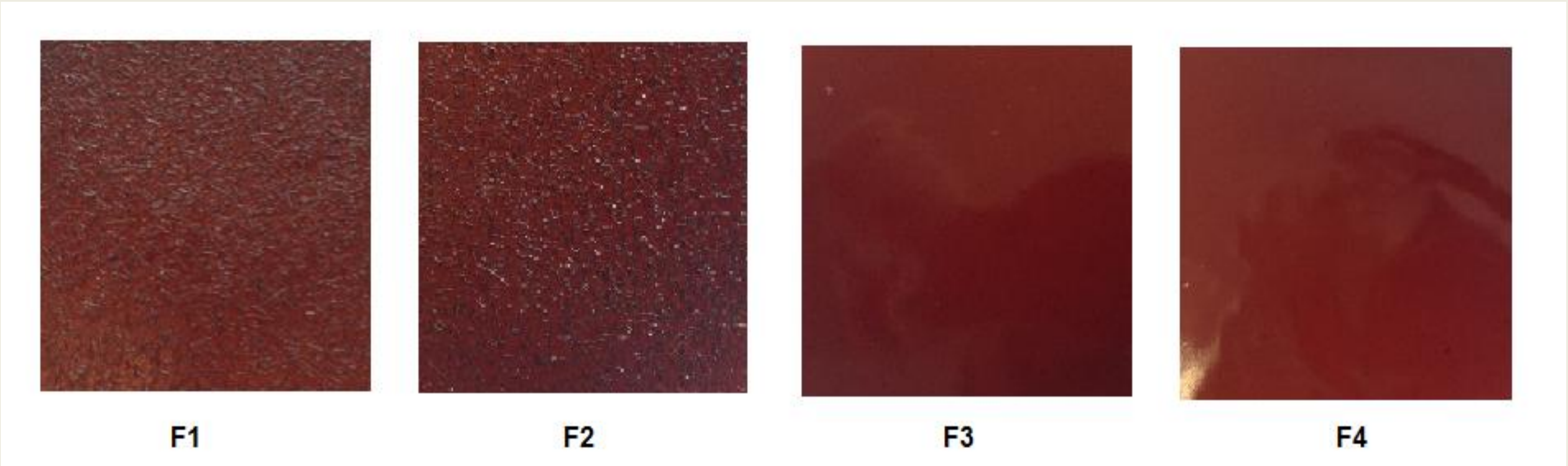
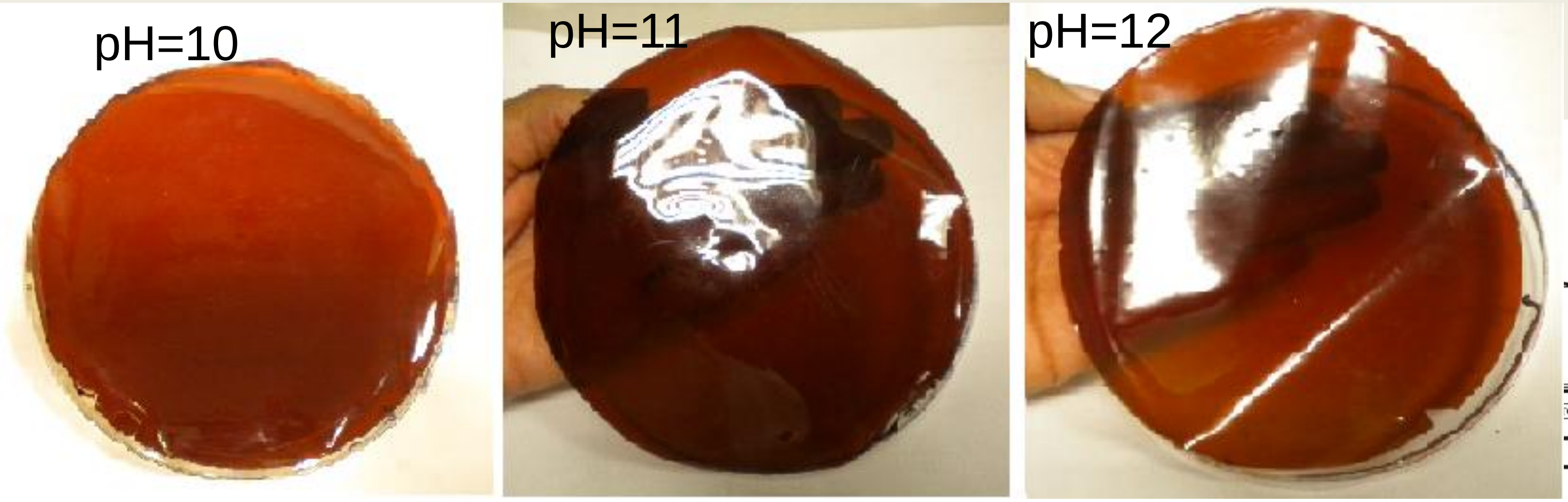
- Filmes a base de proteínas extraídas da torta da mamona



F1=filme com fibra e com glioxal; F2=filme com fibra e sem glioxal; F3=filme sem fibra e com glioxal; F4=filme sem fibra e sem glioxal.

Fonte: Bittante (2015)



Composição centesimal dos dados de matéria seca, proteína e cinzas do resíduo

	Resíduo Seco			
	pH8	pH9	pH10	**pH11**
Matéria seca (%)	91,44 ± 1,01[a]	93,89± 1,30[a]	91,58±1,08[a]	**91,44±2,65[a]**
Proteína (b.s.%)	36,26 ± 1,08[a]	33,40± 0,44[b]	30,79±1,09[c]	**25,84±0,42[d]**
Cinzas (b.s.%)	12,60 ± 0,54[ab]	11,91 ± 0,25[b]	13,40±0,35[a]	**13,55±0,18[a]**

Fonte: Lacerda (2013)

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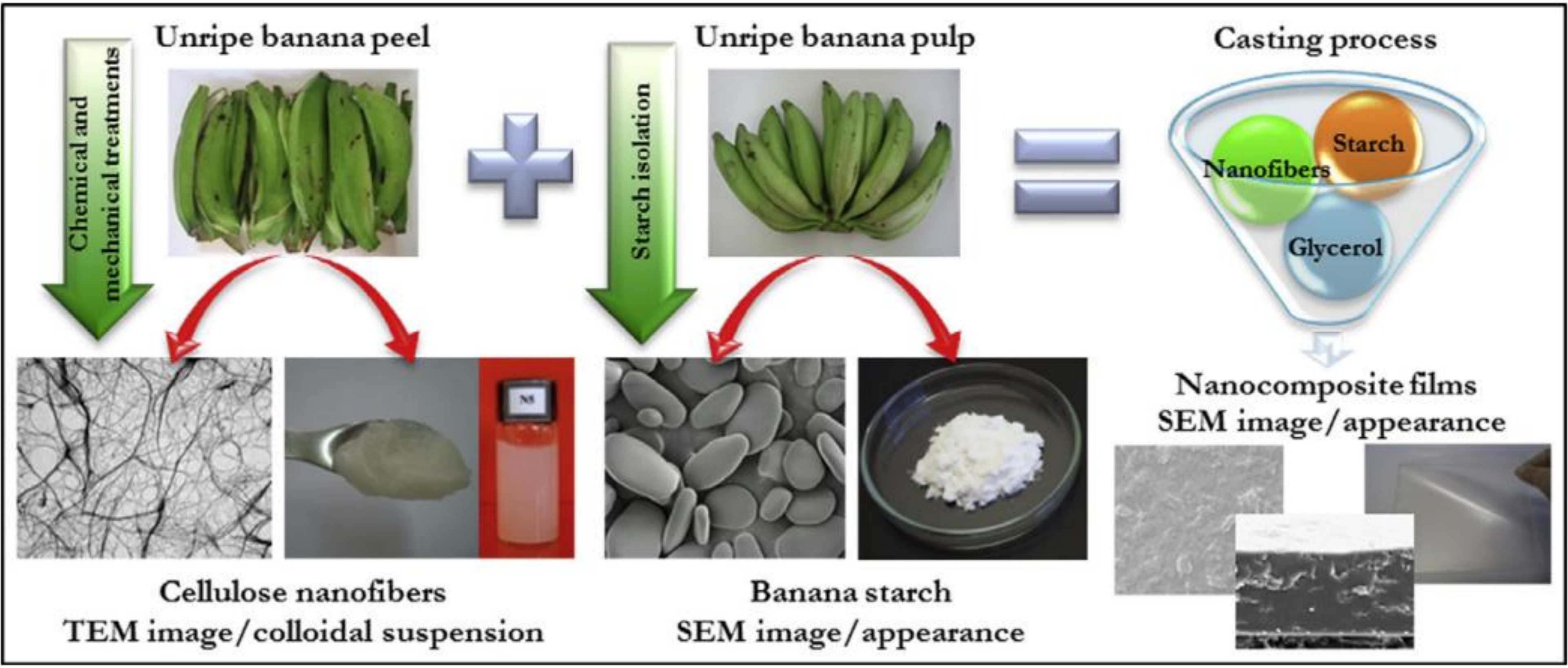
Perfil de aminoácidos dos resíduos de extração das proteínas em NaOH em diferentes pH

Aminoácidos (g/100g proteína)	pH de extração 10	pH de extração 11	pH de extração 12
Alanina	3,61±0,02[a]	3,86±0,02[a]	3,14±0,07[b]
Arginina	9,57 ±0,05[a]	9,89±0,04[a]	7,67±0,01[b]
Acido aspártico	7,16±0,25[a]	7,45±0,21[a]	5,98±0,30[a]
Glicina	3,58±0,03[a]	3,76±0,02[a]	3,23±0,06[b]
Isoleucina	2,93±0,17[a]	3,26±0,06[a]	2,56±0,04[a]
Leucina	5,19±0,11[a]	5,57±0,10[a]	4,54±0,05[b]
Acido glutâmico	13,44±0,06[a]	13,39±0,01[a]	11,63±0,26[b]
Lisina	2,61±0,11[a]	2,47±0,09[a]	1,54±0,01[b]
Cistina	1,82±0,22[a]	0,89±0,09[a]	0,19±0,00[a]
Metionina	1,73±0,13[a]	1,98±0,03[a]	1,69±0,02[a]
Fenilalanina	3,11±0,07[a]	3,33±0,05[a]	2,65±0,04[b]
Tirosina	2,05±0,71[a]	2,21±0,02[a]	1,79±0,05[b]
Treonina	2,70±0,76[a]	3,03±0,01[a]	1,83±0,03[b]
Triptofano	7,89±0,04[a]	7,75±0,06[a]	6,23±0,13[b]
Prolina	3,14±0,03[a]	3,53±0,04[a]	2,61±0,03[b]
Valina	3,37±0,20[a]	3,79±0,13[a]	3,04±0,04[a]
Histidina	2,14±0,08[a]	2,27±0,07[ba]	1,79±0,01[b]
Serina	4,49±0,03[a]	4,71±0,01[a]	3,52±0,11[b]

Fonte: Lacerda (2013)

Cadeia da banana – nanofibras de celulose



Fonte: Pelissari et al., (2017)

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Composição da casca da banana:
Umidade: 5.2 %
Cinzas: 9.8 %
Celulose: 12.1 %
Hemicelulose: 10.2 %
Lignina: 2.9 %.

Fonte: Pelissari et al., (2014)

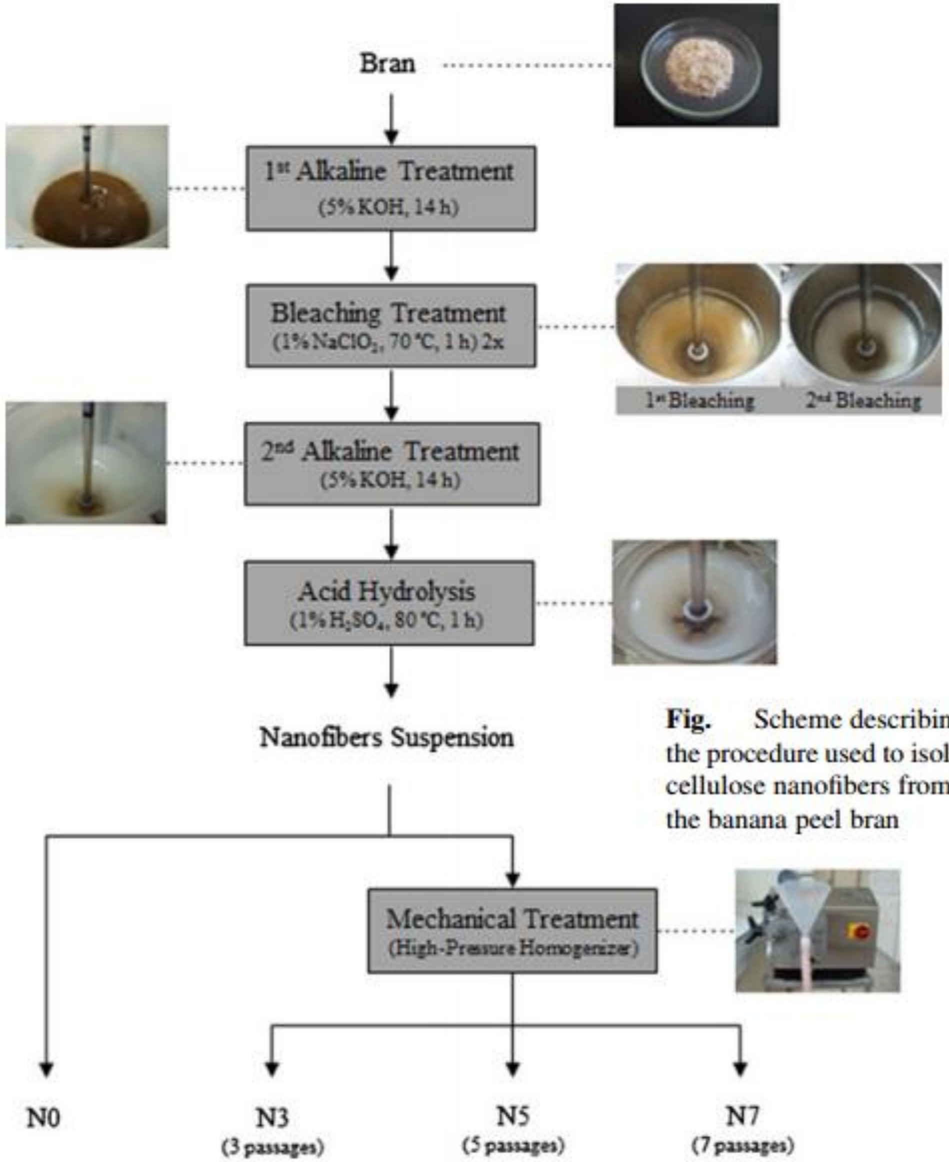

Fig. Scheme describing the procedure used to isolate cellulose nanofibers from the banana peel bran

Tratamento mecânico: homogeneizador de duplo-estágio (GEA Niro Soavi modelo NS 1001L—Panda 2 K, Parma) Italy): 500 e 50 Bar.

Fonte: Pelissari et al., (2014)

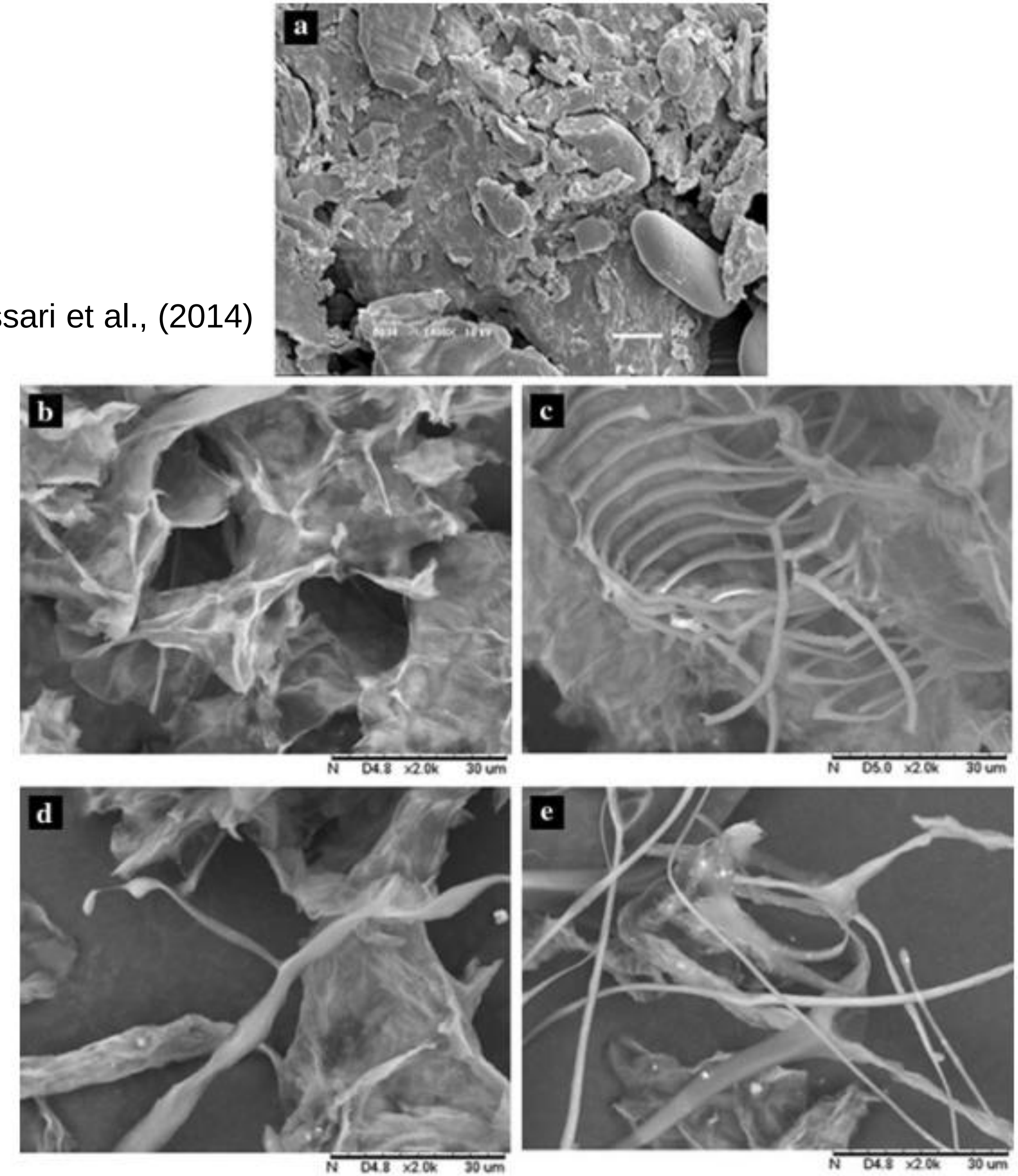

Fig. SEM images of the **a** banana peel bran (×1,000, *scale bar* 10 μm) and of the steps involved in the chemical treatment for the isolation of cellulose nanofibers: **b** first alkaline treatment, **c** first bleaching, **d** second bleaching, and **e** second alkaline treatment (×2,000, *scale bar* 30 μm)

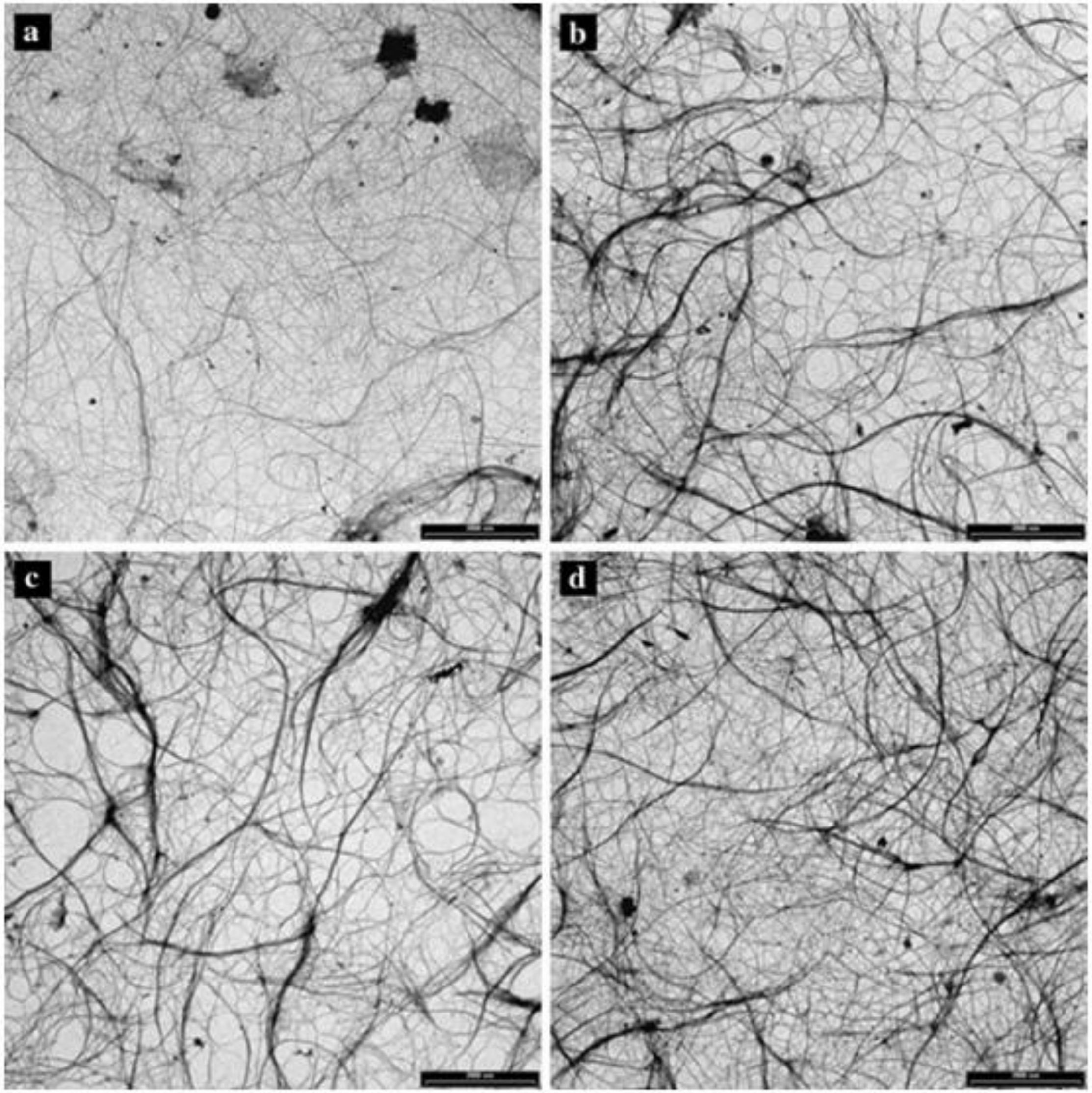

Fig. TEM images of cellulose nanofibers obtained by different number of passages in the high-pressure homogenizer: **a** N0, **b** N3, **c** N5, and **d** N7 (×1,400, *scale bar* 2,000 nm)

Fonte: Pelissari et al., (2014)

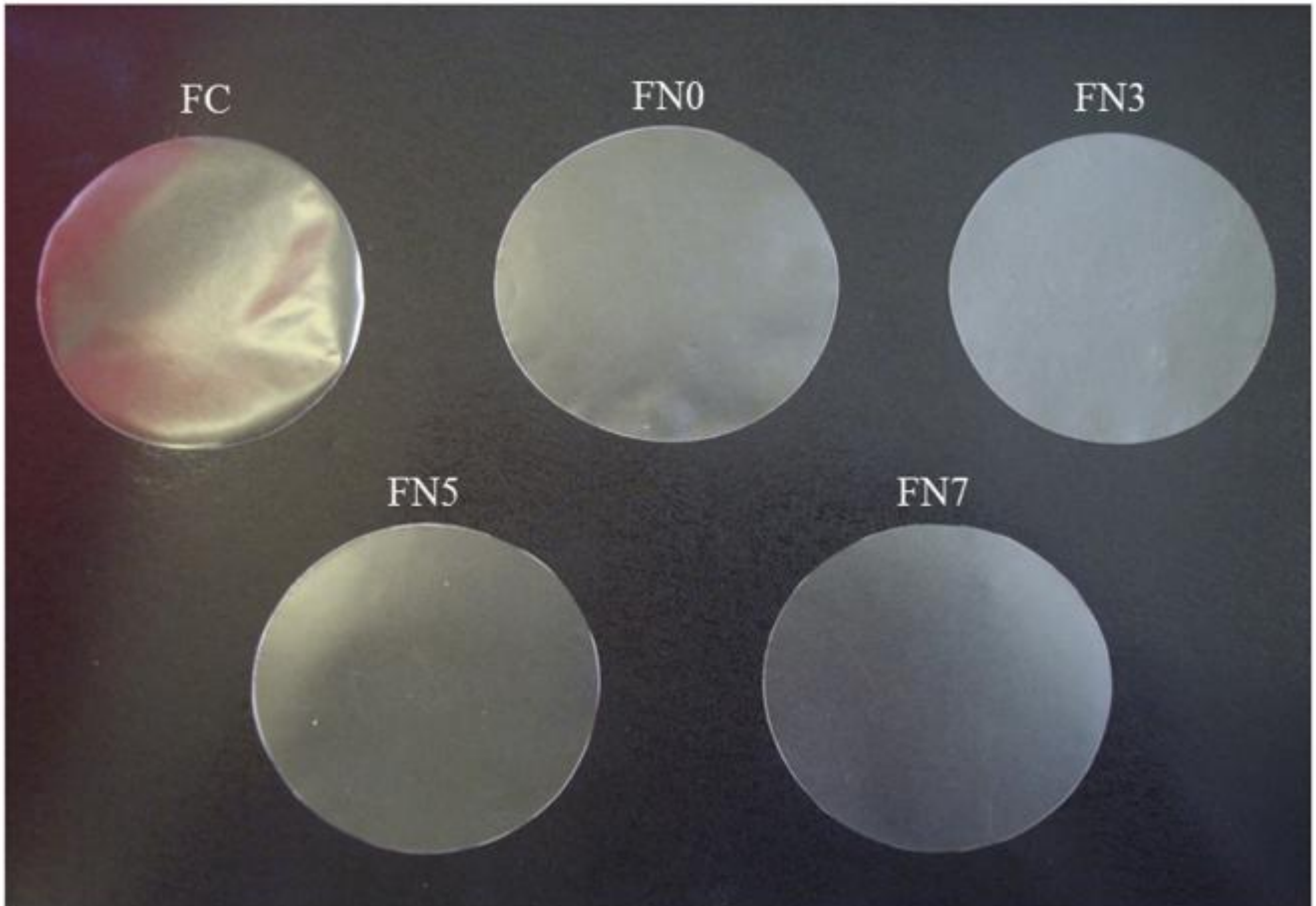

Fig. Appearance of the control film (FC) and nanocomposites reinforced with cellulose nanofibers that were passed through the high-pressure homogenizer zero (FN0), three (FN3), five (FN5), and seven (FN7) times.

Amido extraído da polpa da banana da terra de acordo com Pelissari et al. (2013).

Filmes nanocompósitos:

- 4 g amido/100 g solução

- 5 g nanofibras/100 g amido

- 25 g glicerol/100 g amido

Fonte: Pelissari et al., (2017)

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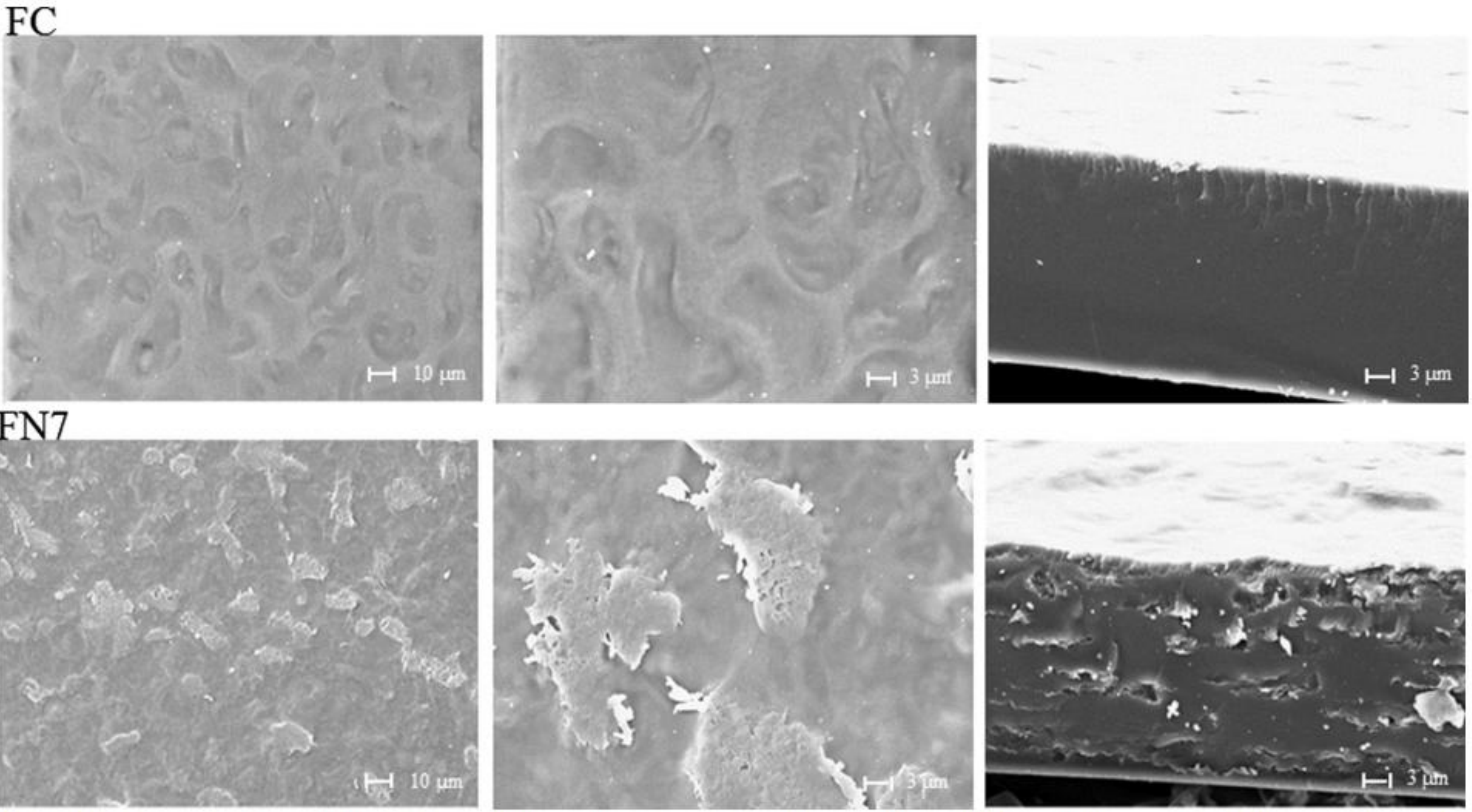

Fig. 1. SEM surfaces (500x, scale bar = 10 μm; 2000x, scale bar = 3 μm) and cross-sections (2000x, scale bar = 3 μm) of the control film (FC) and nanocomposites reinforced with cellulose nanofibers that were passed through the high-pressure homogenizer zero (FN0), three (FN3), five (FN5), and seven (FN7) times.

Fonte: Pelissari et al., (2017)

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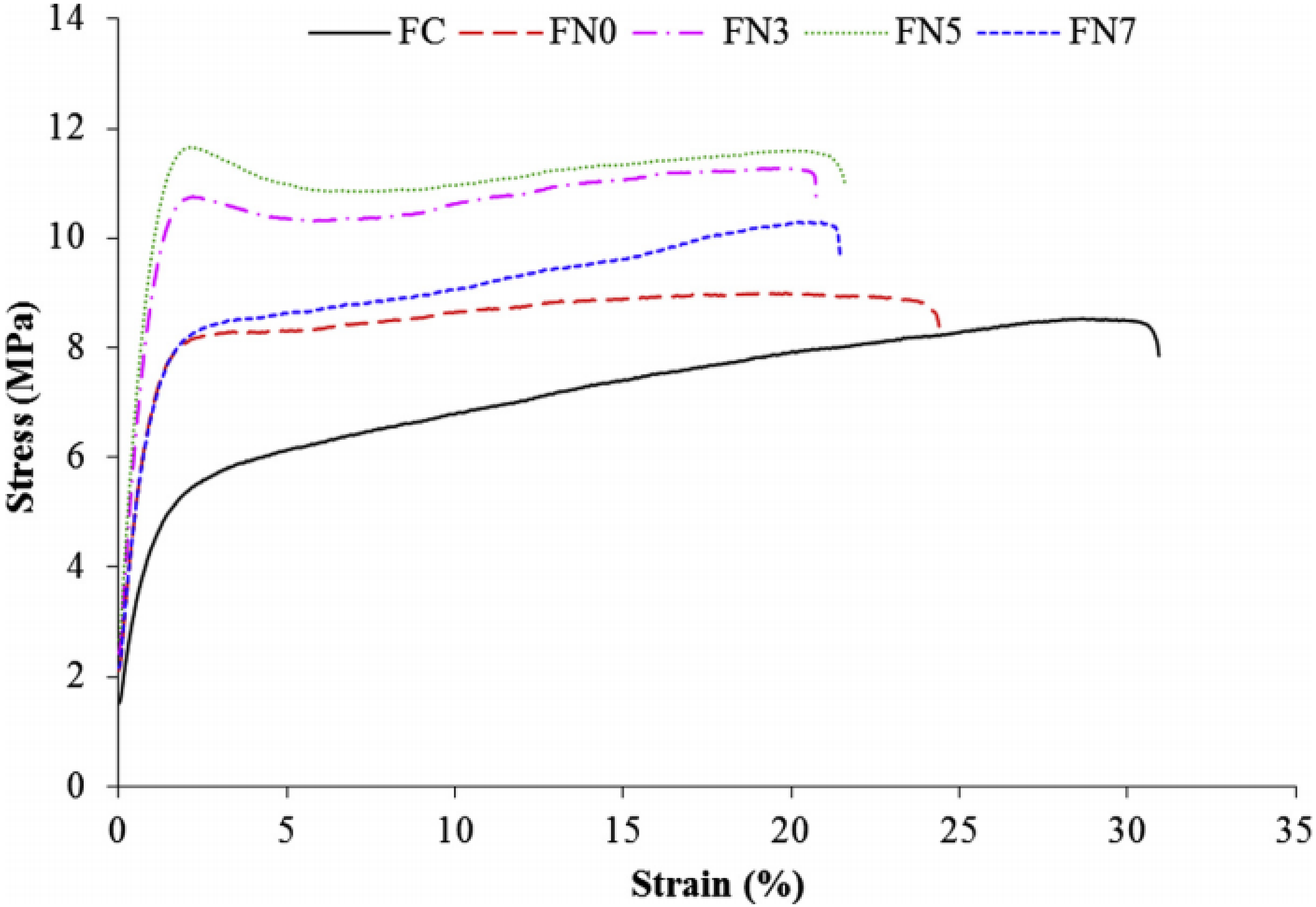

Fig. 3. Typical stress-strain curves obtained for the control film (FC) and nanocomposites reinforced with cellulose nanofibers that were passed through the high-pressure homogenizer zero (FN0), three (FN3), five (FN5), and seven (FN7) times.

Fonte: Pelissari et al., (2017)

Cadeia de ervas – extratos em filmes ativos

Componentes determinados por CG-MS (GC-2010, Shimadzu, Suzhou, China):

Cafeina.

1,8-cineol, ρ-cymeno, fitol, ácido eicosanoico, cis,cis,cis-7,10,13-hexadeca trienal, e α-irono.

Cinamaldehido e α-copaeno.

Eucalyptol, linalol, câmfora, α-pineno, terpinen-4-ol, camfeno, β-pineno, D-limoneno, ρ-cymeno, ácido n-hexadecanoico, endo-borneol, L-α-terpineol, caryofileno, bornyl acetato and tetradecanal.

Fonte: Bonilla & Sobral (2017)

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Table: Results obtained for the extracts in the Trolox equivalent antioxidant capacity (TEAC) and DPPH assays at specific time points and for the Folin-Ciocalteu assay (Mean values with the standard deviations in brackets).

Sample		Rosemary	Boldo	Cinnamon	Guarana
TEAC (mM)	1 min	2.96 (0.04)^{a,x}	5.50 (0.01)^{b,x}	2.53 (0.11)^{c,x}	0.25 (0.01)^{d,x}
	3 min	3.32 (0.24)^{a,y}	6.23 (0.21)^{b,y}	2.75 (0.07)^{c,y}	0.26 (0.01)^{d,y}
	6 min	3.69 (0.42)^{a,z}	6.66 (0.17)^{b,z}	2.86 (0.06)^{c,z}	0.26 (0.01)^{d,z}
DPPH (mg/l)	15 min	0.37 (0.02)^{a,x}	0.23 (0.02)^{b,x}	0.06 (0.01)^{a,x}	0.10 (0.01)^{c,x}
	30 min	0.48 (0.02)^{a,y}	0.37 (0.03)^{b,y}	0.13 (0.04)^{a,y}	0.14 (0.01)^{c,y}
	45 min	0.80 (0.14)^{a,z}	0.56 (0.05)^{b,z}	0.23 (0.02)^{c,z}	0.26 (0.04)^{c,z}
Folin–Ciocalteu (mg GA/g extract)	---	115.00 (0.01)^{a}	108.00 (0.04)^{a}	172.00 (0.03)^{a}	139.00 (0.03)^{a}

The same superscript (abc) compares different extracts horizontally and (xyz) compare them vertically at different times in the LSD test. Values with different letters differ significantly in same row. Level of significance: 95.0%.

Fonte: Bonilla & Sobral (2017)

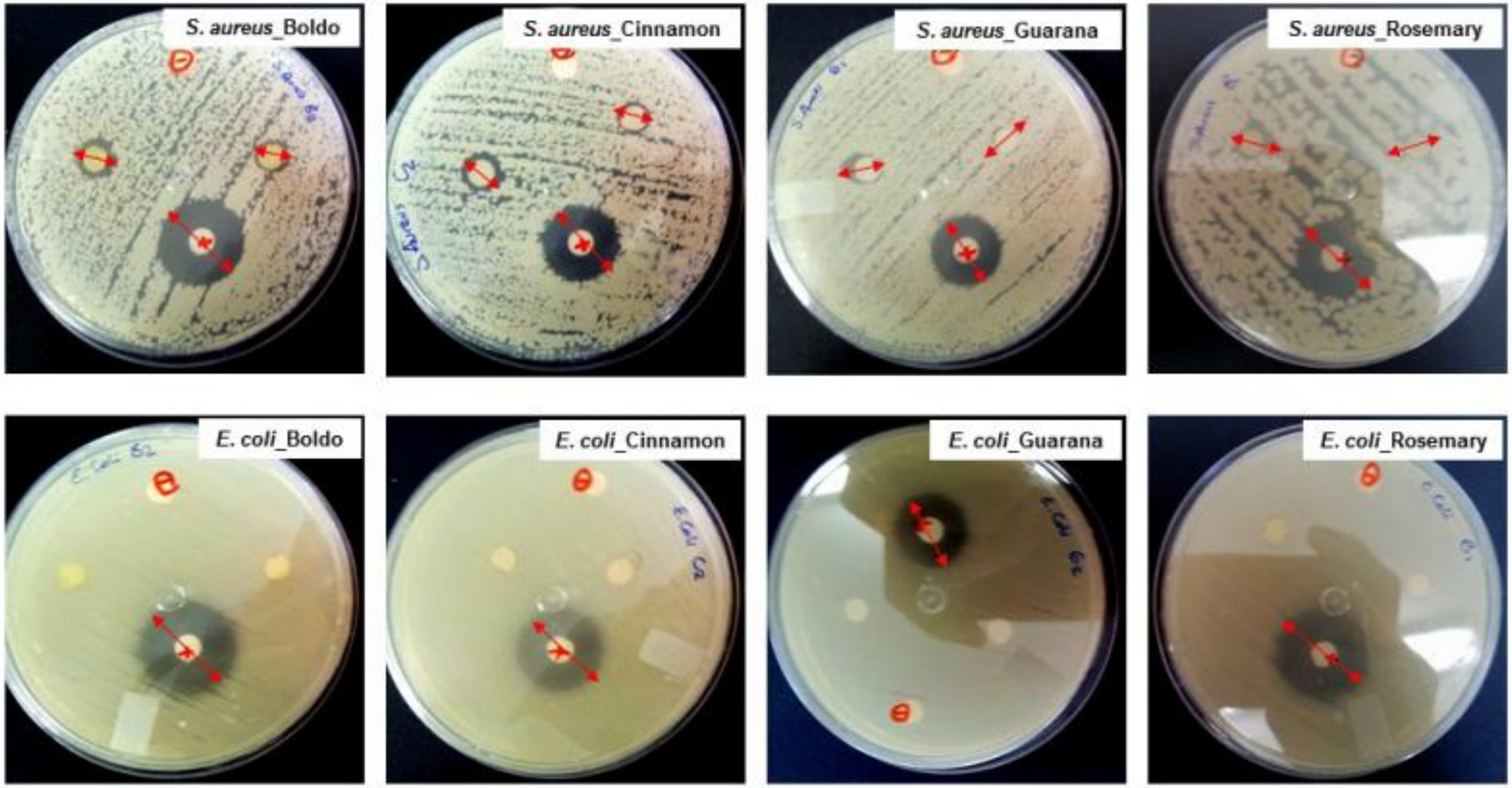

Figure . Inhibition of bacterial growth *(E. Coli* and *S. Aureus*) by the boldo of Chile (*Peumus boldus molina*), cinnamon (*Cinnamomum sp.*), guarana (*Paullinia cupana) and* rosemary (*Rosmarinus officinalis*) extracts.

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Fonte: Bonilla & Sobral (2017)

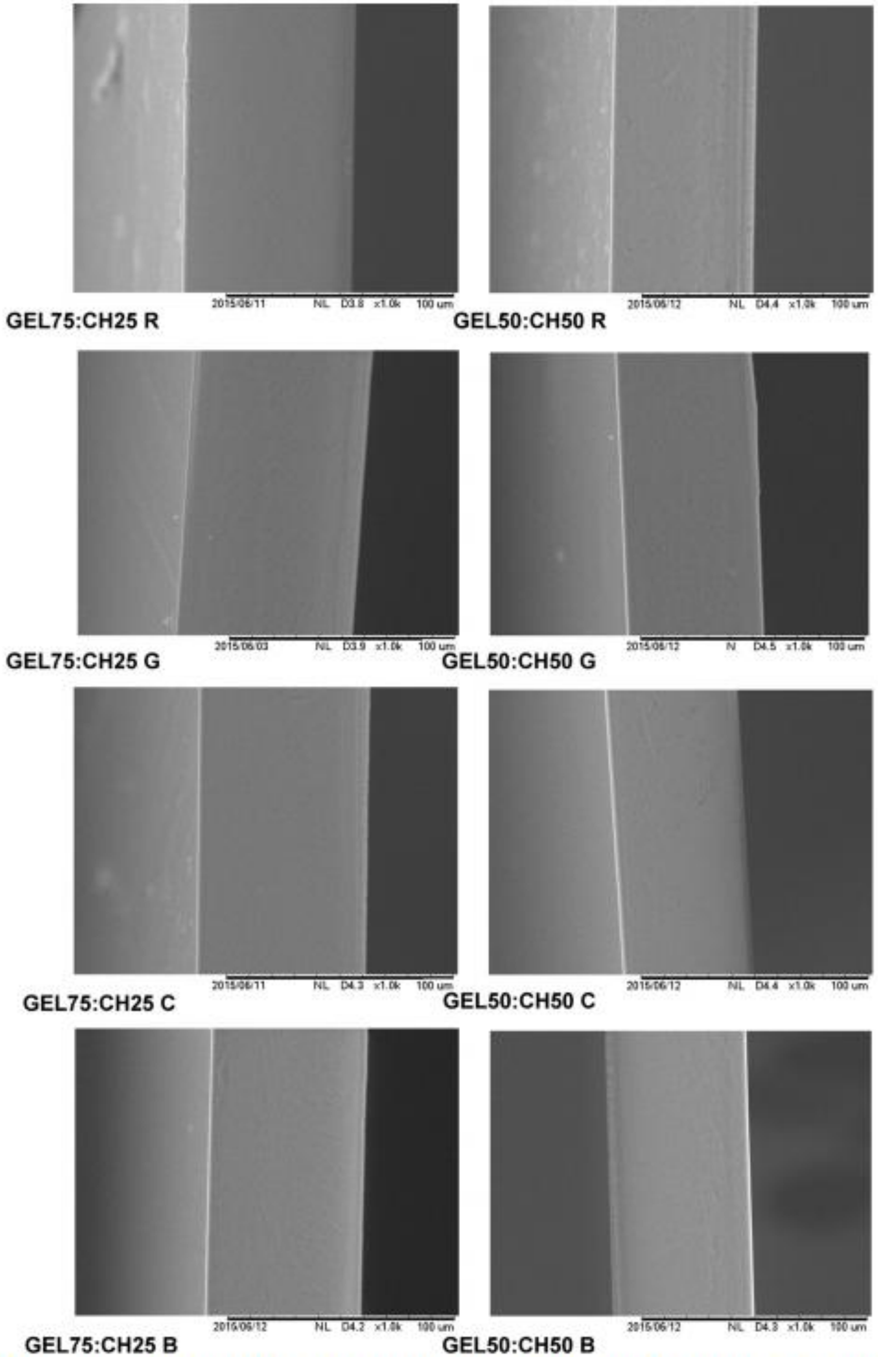

Fig. Scanning electron microscopy (SEM) images of cross-sections of blend films (Gel75:CH25 or GEL50:CH50) with guarana (G), boldo (B), cinnamon (C) and rosemary (R) extracts.

Fonte: Bonilla & Sobral (2016)

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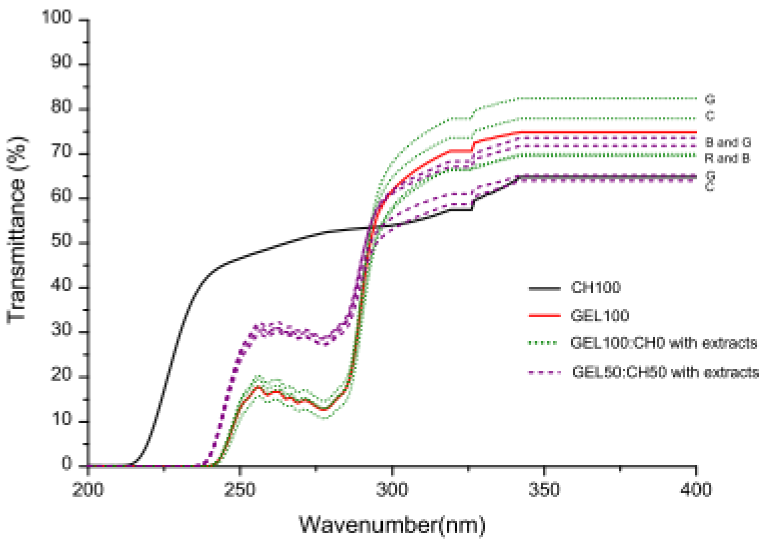

Fig. UV-Vis spectra for pure chitosan films (CH100), pure gelatin films (GEL100) and GEL100:CH0 and GEL50:CH50 blend films with guarana (G), boldo (B), cinnamon (C) and rosemary (R) extracts.

Table
Trolox equivalent antioxidant capacity (TEAC) of the films (mg/l) with or without ethanolic extract at specific time points.

Film	Extract	1 min	3 min	6 min	SEM
GEL100	Without	–	–	–	–
CH100	Without	$0.15^{C,d}$	$0.16^{C,d}$	$0.16^{C,d}$	0.13
GEL 75:CH25	Boldo	$0.94^{B,a}$	$1.4^{B,a}$	$1.5^{B,a}$	0.13
GEL 50:CH50		$1.1^{A,a}$	$1.5^{A,a}$	$1.8^{A,a}$	0.13
GEL 75:CH25	Rosemary	$0.17^{B,b}$	$0.21^{B,b}$	$0.27^{B,b}$	0.13
GEL 50:CH50		$1.2^{A,b}$	$1.6^{A,b}$	$1.9^{A,b}$	0.13
GEL 75:CH25	Cinnamon	$0.17^{B,c}$	$0.23^{B,c}$	$0.31^{B,c}$	0.13
GEL 50:CH50		$0.27^{A,c}$	$0.31^{A,c}$	$0.32^{A,c}$	0.13
GEL 75:CH25	Guarana	$0.89^{B,ab}$	$1.2^{B,ab}$	$1.5^{B,ab}$	0.13
GEL 50:CH50		$0.93^{A,ab}$	$1.3^{A,ab}$	$1.6^{A,ab}$	0.13

–– Not showed antioxidant capacity. GEL: Gelatin; CH: Chitosan. Means with the same superscript (^{ABCD}) were compared vertically for different GEL:CH ratios, and means (^{abcd}) were compared vertically for different extracts in LSD test. SEM: Standard error of the mean based on Mean Square Error of ANOVA analysis.

Fonte: Bonilla & Sobral (2016)

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Cadeia de ervas – extratos como aditivos

Extrato de folhas de pitanga (EFP) foi estudado como aditivo antioxidante e antimicrobiano em “burgers” de carne suína embalada em atmosfera modificada e estocada a 2 ºC.

Cinco tratamentos:

i) Sem antioxidante.

ii) Com BHT (200 mg/kg).

iii) Com EFP (250, 500 e 1000 mg/kg).

Foram identificados (UHPLC-ESI/QTOF): ácido hidroxi-cinâmico, tirosol e outros fenólicos (acilmetoxifenois, hidroxicomarinos e hidroxifenilpropenos).

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Fonte: Lorenzo et al. (2018)

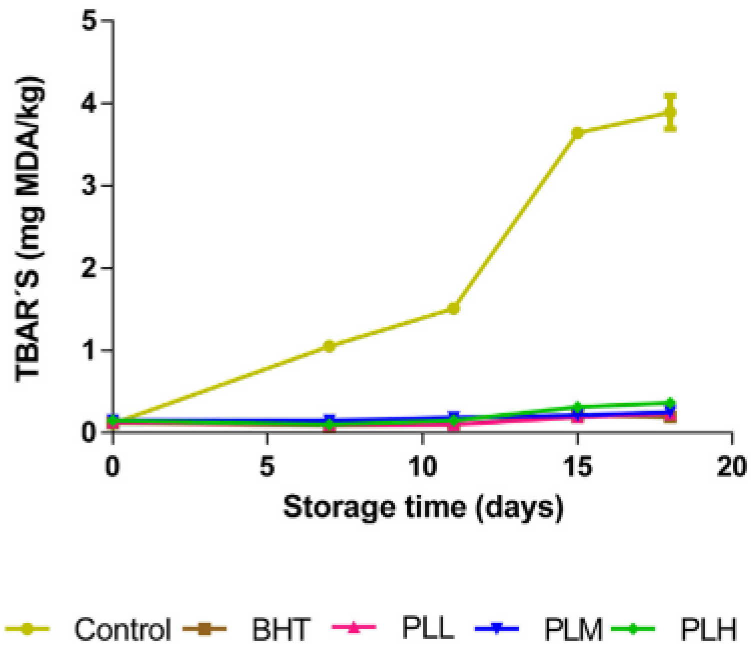

Fig. Effect of addition of antioxidant on the evolution of TBARS values of pork burgers packed under modified atmosphere packaging (80% O_2 + 20% CO_2) during storage at 2 ± 1 °C. Treatments: CON: control, without antioxidant; BHT: Butylated hydroxytoluene at 200 mg/kg; PLL pitanga leaf extracts at 250 mg/kg; PLM: pitanga leaf extracts at 500 mg/kg; PLH: pitanga leaf extracts at 1000 mg/kg;

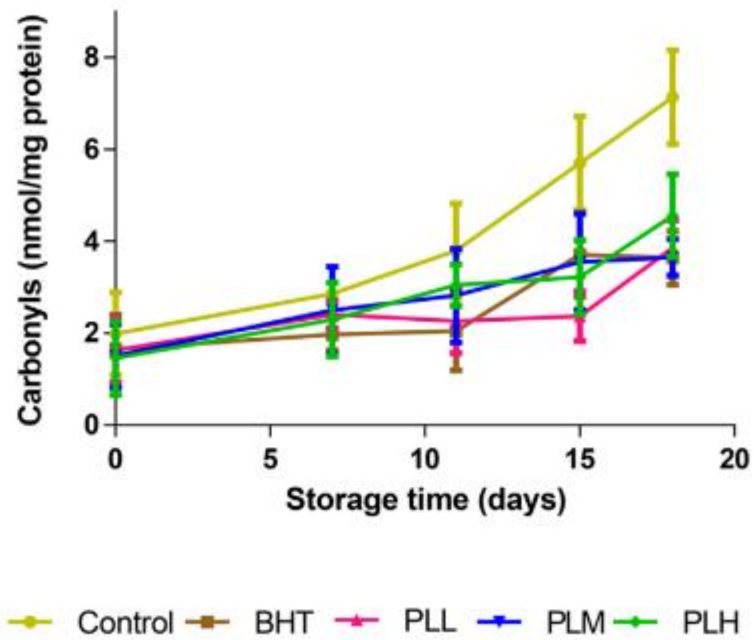

Fig. Effect of addition of antioxidant on the evolution of carbonyl of pork burgers packed under modified atmosphere packaging (80% O_2 + 20% CO_2) during storage at 2 ± 1 °C. Treatments: CON: control, without antioxidant; BHT: Butylated hydroxytoluene at 200 mg/kg; PLL pitanga leaf extracts at 250 mg/kg; PLM: pitanga leaf extracts at 500 mg/kg; PLH: pitanga leaf extracts at 1000 mg/kg;

Fonte: Lorenzo et al. (2018)

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Considerações finais

- Bioeconomia e biorefinarias envolvem produção e processamento de Alimentos.
- Alimentos seguros e a segurança alimentar devem estar nesse contexto.
- Estudos mais sistêmicos são necessários.
- Custos?
- Água, Energia e Alimentos não são inesgotáveis!

Muito obrigado pela atenção!!!

Prof. Paulo Sobral, pjsobral@usp.br

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