

Bioconversion of agricultural  
waste hydrolysate from  
lignocellulolytic mold into  
biosurfactant by  
Achromobacter sp. BP(1)5  
*by Ni'matuzahroh Ni'matuzahroh*

---

**Submission date:** 26-Apr-2021 11:19AM (UTC+0800)

**Submission ID:** 1569783575

**File name:** 5\_Bioconversion\_of\_agricultural.pdf (1.66M)

**Word count:** 5792

**Character count:** 31307



Contents lists available at ScienceDirect

# Biocatalysis and Agricultural Biotechnology

journal homepage: <http://www.elsevier.com/locate/bab>



## Bioconversion of agricultural waste hydrolysate from lignocellulolytic mold into biosurfactant by *Achromobacter* sp. BP(1)5

Ni' matuzahroh<sup>a,b,\*</sup>, Silvia Kurnia Sari<sup>a,b</sup>, Nastiti Trikurniadewi<sup>a,b</sup>,  
Syahriar Nur Maulana Malik Ibrahim<sup>a,b</sup>, Ana Mariatul Khiftiyah<sup>a,b</sup>, Achmad Zainal Abidin<sup>a</sup>,  
Tri Nurhariyati<sup>a,b</sup>, Fatimah<sup>a,b</sup>

<sup>a</sup> Department of Biology, Faculty of Science and Technology, Universitas Airlangga, Surabaya, 60115, Indonesia

<sup>b</sup> Research Center for Bio-Molecule Engineering, Universitas Airlangga, Surabaya, 60115, Indonesia

### ARTICLE INFO

#### Keywords:

Agricultural waste  
Bioconversion  
Biosurfactant  
Lignocellulolytic mold

### ABSTRACT

Rice straw and corn cobs have proven as a promising waste in the bioconversion of biomass into bioproducts. The lignocellulose content found in rice straw and corn cobs has the potential to be hydrolyzed into sugar and used as a carbon source for the growth of microorganisms. This study aims to utilize lignocellulose waste from rice straw and corn cobs for biosurfactant production by *Achromobacter* sp. BP(1)5. Rice straw and corn cobs were hydrolyzed using *Penicillium citrinum* H9 4% (v/v) for 6 days. Sugar content was analyzed using the Somogyi-Nelson method with UV-Visible spectrophotometer. Biosurfactants were produced in synthetic mineral water by adding hydrolysate sugar from rice straw and corn cobs for 7 days and evaluated through measurement of surface tension and emulsification activity. *Achromobacter*'s biosurfactant crude extracts were characterized by critical micelle concentration (CMC) value and stability at the variation in pH, temperature, and salinity. *Achromobacter* sp. BP(1)5 was identified using 16S rRNA. The yields of sugar from rice straw and corn cobs hydrolysis sequentially were 2.260 and 7.880 g/L. The crude biosurfactant from hydrolysate sugar substrate of rice straw and corn cobs had same CMC value that was 6.0 g/L with emulsification activity on kerosene 27.22% and 36.84% respectively. Crude biosurfactant extracts from both substrates were stable on pH 4.0–10.0, temperature 30–70 °C and salinity 0–10% (w/v). This study showed that the agricultural wastes were a cheap material for biosurfactant production, thereby reducing obstacles for biosurfactant production.

### 1. Introduction

Indonesia is an agrarian country that produces rice and corn in large quantities compared to other agricultural crops. Based on Statistics Indonesia, in Indonesia as many as 75.40 and 19.60 million tons of rice and corn were produced in 2015 (Subagya et al., 2016). Along with the high production of rice and corn, the by-product derived from these two plants, for example corn cobs and rice straw, are also quite abundant in the environment. In Indonesia the use of corn cob and rice straw has not been done much and is less varied, utilization by the community generally only as animal feed and compost.

Rice straw and corn cobs contain lignocelluloses, which consist of lignin, cellulose, and hemicellulose (Shawky et al., 2011; Ghaffar et al., 2017; Mardawati et al., 2018). Several researches proved that lignocellulose biomass from agricultural wastes can be converted into many

products (Sunarti et al., 2010; Ghaffar et al., 2017), one of them is into substrates for biosurfactant production (Das and Kumar, 2018; Ni' matuzahroh et al., 2019a; Ni' matuzahroh et al., 2019b).

Biosurfactant is surface-active chemical compounds synthesized by several bacteria and fungi that can be applied in many fields, such as for remediation of oil and heavy metal contaminated sites (Qiao and Shao, 2010; Nwaguma et al., 2016; Goma and El-Meihy, 2019; Pele et al., 2019). Biosurfactant is an alternative to non-biodegradable and environmentally harmful surfactants (Moro et al., 2018). Although biosurfactants are save for the environment, biosurfactant production is still expensive (Helmy et al., 2011). Hence many researches has been done to minimize the cost of biosurfactant production by utilizing less valuable raw material (Martins and Martins, 2018; Pele et al., 2019). Some researches showed that agricultural wastes could be the low-cost substrate candidate for biosurfactant production (Moldes et al., 2007;

\* Corresponding author. Department of Biology, Faculty of Science and Technology, Universitas Airlangga, Surabaya, 60115, Indonesia.  
E-mail address: [nimatuzahroh@fst.unair.ac.id](mailto:nimatuzahroh@fst.unair.ac.id) (Ni' matuzahroh).

<https://doi.org/10.1016/j.bcab.2020.101534>

Received 23 October 2019; Accepted 7 February 2020

Available online 8 February 2020

1878-8181/© 2020 Elsevier Ltd. All rights reserved.

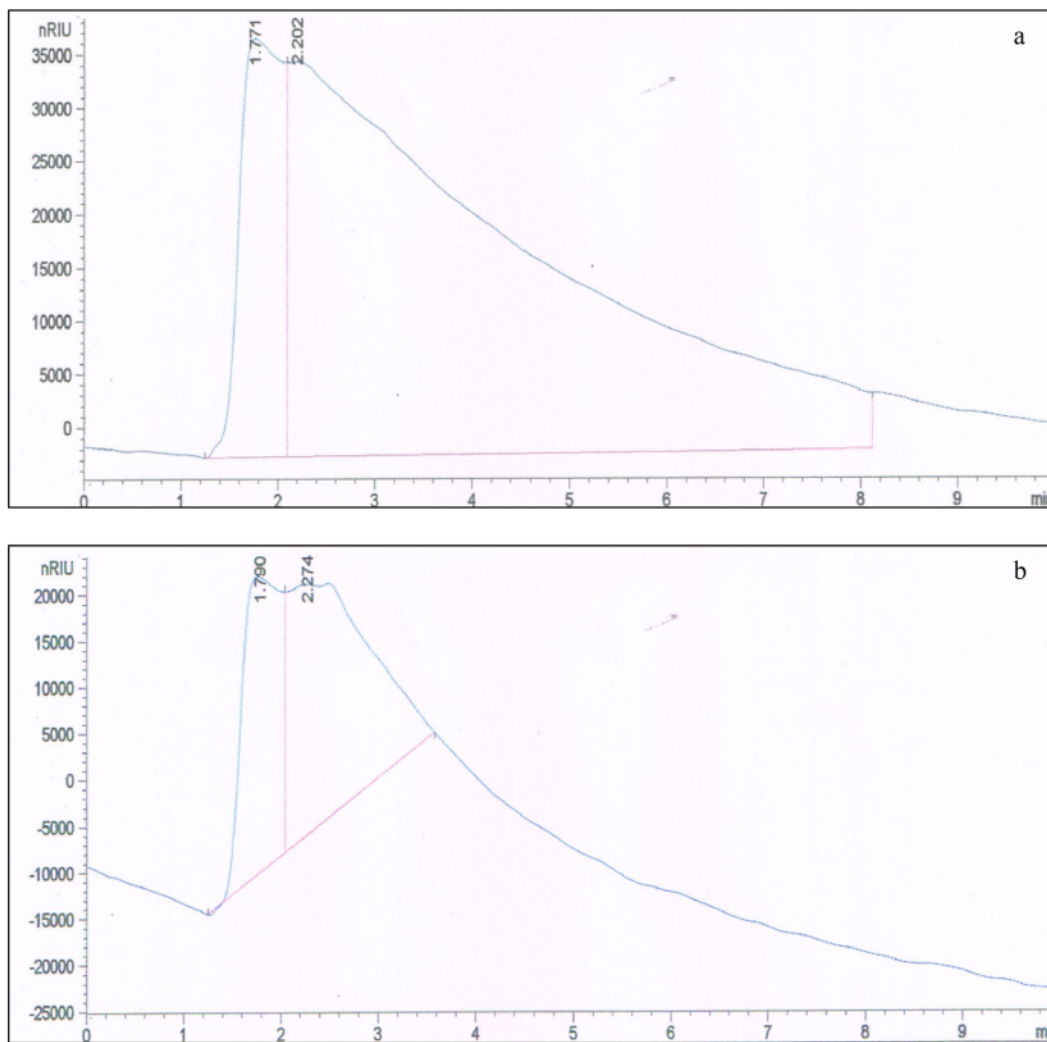


Fig. 1. HPLC chromatogram of agricultural wastes hydrolysate produced by *Penicillium citrinum* sp. H9 from different substrates (a) rice straw and (b) corn cobs.

7  
Ni'matuzahroh et al., 2019a; Ni'matuzahroh et al., 2019b).

Utilization of agricultural waste in bioconversion to biosurfactants involved hydrolysis as pre-treatment for agricultural waste to produce hydrolysate sugar that would be used as a substrate (Moldes et al., 2007). Hydrolysis of agricultural waste could be carried out using enzymes (Boonmee, 2012) and living cell (Ni'matuzahroh et al., 2019b). *Penicillium citrinum* H9 is one of the lignocellulolytic molds that have been known its potency in agricultural waste hydrolysis (Ni'matuzahroh et al., 2019a; Ni'matuzahroh et al., 2019b). As many as 209.25 µg/mL sugar was obtained from the hydrolysis of rice straw by *Penicillium citrinum* H9 (Ni'matuzahroh et al., 2019b).

Besides using low-cost material to overcome the problem in biosurfactant production, another solution is applied good potent biosurfactant producing bacteria (Dos Reis et al., 2018). Hydrocarbonoclastic bacteria, *Achromobacter* sp. BP(1)5 that isolated from Balongan oil sludge was one of the potential bacteria in producing biosurfactant from rice straw hydrolysate than the others isolates (Ni'matuzahroh et al., 2019a). The ability of the bacteria to produce biosurfactant in low-cost substrate indicates the bacteria as a promising isolate for low-cost biosurfactant production. The aims of this research

were: to utilize hydrolysate sugar from rice straw and corn cobs through the hydrolysis carried out by *Penicillium citrinum* H9 for biosurfactant production by *Achromobacter* sp. BP (1)5, and to characterize the biosurfactants yielded in each agricultural wastes hydrolysate substrate. Besides that, the identification of the potential bacteria was carried out to reveal another potency that might be had by the bacteria. This research was not only being expected to provide alternatives in biosurfactant production, but also can increase the value of agricultural wastes utilization so that they can be used more widely and reduce the amount of organic waste in the environment.

## 2. Materials and methods

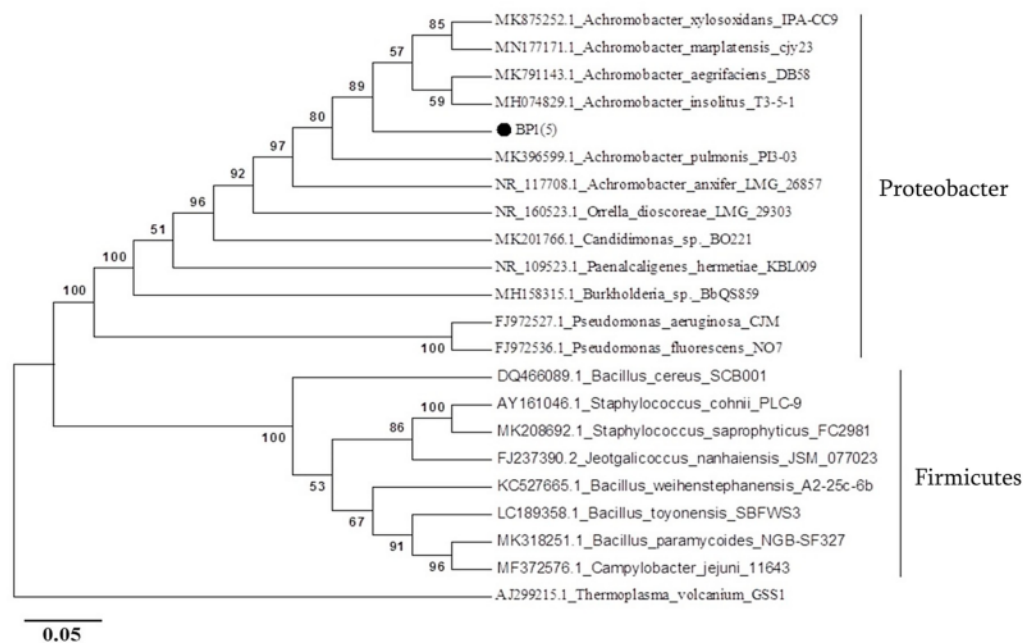
### 2.1. Isolate and medium preparation

*Penicillium citrinum* H9 and *Achromobacter* sp. BP(1)5 are a microbial collection from microbiology laboratory of Biology Department, Universitas Airlangga. *Penicillium citrinum* H9 was re-cultured on Potato Dextrose Agar (PDA) slant and was incubated in room temperature 28 °C for seven days. *Achromobacter* sp. BP(1)5 isolate was grown in nutrient

**a**

Isolate (Taxon)	Taxon / Taxon																						
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	
<i>Achromobacter</i> BP1(5)	1		0.077	0.019	0.016	0.019	0.010	0.006	0.006	0.006	0.006	0.034	0.034	0.035	0.034	0.031	0.031	0.031	0.031	0.029	0.029	0.029	
AJ299215.1_Thermoplasma_volcanium_GSS1	2	0.642		0.031	0.030	0.064	0.030	0.030	0.030	0.030	0.037	0.030	0.028	0.028	0.027	0.034	0.032	0.032	0.031	0.031	0.029	0.029	
NR_109523.1_Paenacaligenes_hemetiae_KBL009	3	0.094	0.578		0.007	0.018	0.007	0.008	0.008	0.008	0.011	0.008	0.017	0.017	0.017	0.021	0.019	0.018	0.018	0.018	0.013	0.013	
MK201766.1_Candidimonas_sp_BO221	4	0.073	0.590	0.069		0.015	0.004	0.005	0.004	0.006	0.005	0.008	0.005	0.018	0.017	0.018	0.020	0.018	0.018	0.018	0.012	0.013	
MH158315.1_Burkholderia_sp_BbQS859	5	0.094	0.649	0.119	0.103		0.016	0.017	0.018	0.017	0.017	0.017	0.018	0.031	0.031	0.030	0.033	0.027	0.028	0.028	0.028	0.025	0.024
NR_160523.1_Orella_dioscoreae_LMG_29303	6	0.025	0.585	0.082	0.029	0.100		0.004	0.004	0.005	0.004	0.007	0.004	0.017	0.017	0.018	0.020	0.017	0.017	0.017	0.013	0.013	
MK875252.1_Achromobacter_xylosoxidans_IPA-CC9	7	0.010	0.577	0.085	0.032	0.111	0.025		0.002	0.000	0.002	0.002	0.002	0.018	0.018	0.018	0.020	0.018	0.018	0.018	0.013	0.013	
NR_117708.1_Achromobacter_anxifer_LMG_26857	8	0.010	0.583	0.083	0.027	0.114	0.021	0.004		0.003	0.002	0.005	0.002	0.018	0.017	0.018	0.020	0.018	0.018	0.018	0.013	0.013	
MN177171.1_Achromobacter_marplatensis_cjy23	9	0.010	0.592	0.092	0.048	0.111	0.042	0.000	0.021		0.002	0.004	0.003	0.018	0.018	0.018	0.020	0.018	0.018	0.018	0.013	0.013	
MK791143.1_Achromobacter_aegrifaciens_DB58	10	0.010	0.566	0.086	0.031	0.111	0.024	0.005	0.004	0.005		0.002	0.003	0.017	0.017	0.018	0.020	0.018	0.018	0.018	0.013	0.012	
MH074829.1_Achromobacter_insolitus_T3-5-1	11	0.010	0.642	0.119	0.061	0.111	0.047	0.003	0.024	0.019	0.004		0.004	0.023	0.022	0.023	0.027	0.023	0.022	0.022	0.022	0.016	0.016
MK396599.1_Achromobacter_pulmonis_PI-03	12	0.010	0.584	0.083	0.032	0.114	0.026	0.004	0.005	0.021	0.009	0.021		0.018	0.017	0.018	0.020	0.018	0.018	0.017	0.013	0.013	
AY161046.1_Staphylococcus_cohnii_PLC-9	13	0.271	0.544	0.304	0.318	0.308	0.311	0.310	0.318	0.321	0.305	0.345	0.318		0.001	0.009	0.013	0.009	0.009	0.008	0.008	0.017	0.016
MK208692.1_Staphylococcus_saprophyticus_FC2981	14	0.271	0.544	0.305	0.318	0.308	0.313	0.309	0.318	0.322	0.304	0.343	0.318	0.001		0.009	0.013	0.009	0.009	0.008	0.008	0.017	0.016
FJ237390.2_Jeotgalecoccus_nanhaiensis_JSM_077023	15	0.302	0.517	0.306	0.320	0.273	0.319	0.303	0.324	0.318	0.304	0.339	0.319	0.106	0.105		0.013	0.010	0.009	0.009	0.009	0.017	0.015
DQ466089.1_Bacillus_cereus_SCB001	16	0.283	0.543	0.313	0.301	0.314	0.304	0.305	0.307	0.305	0.309	0.338	0.302	0.134	0.134	0.147		0.009	0.010	0.009	0.009	0.019	0.019
KC527665.1_Bacillus_weihenstephanensis_A2-25c-6b	17	0.260	0.505	0.282	0.262	0.263	0.264	0.267	0.265	0.267	0.267	0.291	0.267	0.078	0.078	0.089	0.072		0.005	0.004	0.004	0.016	0.016
LC189358.1_Bacillus_toyonensis_SBFWS3	18	0.260	0.509	0.276	0.267	0.262	0.266	0.265	0.269	0.265	0.271	0.283	0.265	0.078	0.079	0.085	0.087	0.027		0.003	0.003	0.017	0.016
MK318251.1_Bacillus_paramycoides_NGB-SF327	19	0.260	0.501	0.275	0.265	0.262	0.264	0.264	0.267	0.264	0.270	0.285	0.264	0.070	0.071	0.078	0.074	0.018	0.011		0.001	0.016	0.016
MF372576.1_Campylobacter_jejuni_11643	20	0.260	0.499	0.274	0.264	0.262	0.262	0.263	0.266	0.263	0.268	0.283	0.263	0.069	0.070	0.077	0.074	0.017	0.010	0.001		0.016	0.016
FJ972527.1_Pseudomonas_aeruginosa_CJM	21	0.196	0.567	0.199	0.188	0.214	0.193	0.193	0.197	0.199	0.193	0.241	0.198	0.267	0.266	0.274	0.256	0.220	0.231	0.225	0.224		0.007
FJ972536.1_Pseudomonas_fluorescens_NO7	22	0.199	0.545	0.204	0.211	0.197	0.215	0.194	0.204	0.204	0.188	0.237	0.208	0.262	0.263	0.262	0.237	0.202	0.214	0.208	0.207	0.070	

**b**



**Fig. 2.** (a) Distance pair data of *Achromobacter* sp. BP1(5) and others bacteria; (b) Phylogenetic tree using the Neighbor-Joining method, *Thermoplasma volcanium* was used as out group.



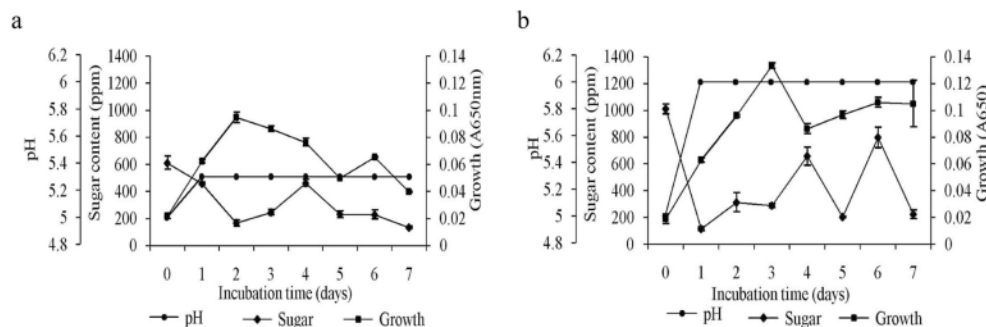


Fig. 3. Growth response of *Achromobacter* sp. BP(1)5 during biosurfactant production for seven days incubation on agricultural waste hydrolysates from different substrates (a) rice straw and (b) corn cobs.

broth medium and incubated using a shaker at 30 °C for 24 h.

The agricultural wastes, rice straw and corn cobs were obtained from Bojonegoro farmer and it were delignified mechanically using grinding and sifted by 40-mesh, then chemically delignified by 1% (w/v) NaOH for 1 h at 100 °C. After delignification, the wastes were washed in water flow until the pH 7 and dried in oven at 60 °C for overnight. Medium that used for saccharification was 100 mL of Mandel Stenberg Mineral (MSM) consisting of 1.4 g/L (NH<sub>4</sub>)<sub>2</sub>SO<sub>4</sub>, 2.0 g/L KH<sub>2</sub>PO<sub>4</sub>, 0.3 g/L CaCl<sub>2</sub>, 0.3 mg/L MgSO<sub>4</sub>·7H<sub>2</sub>O, 5 mg/L FeSO<sub>4</sub>·7H<sub>2</sub>O, 1.6 mg/L MnSO<sub>4</sub>·H<sub>2</sub>O, 1.4 mg/L ZnSO<sub>4</sub>·7H<sub>2</sub>O, 2 mg/L CoCl<sub>2</sub>, 2% (w/v) dried substrates and pH 5 that controlled by citric buffer.

Biosurfactant production was carried out on 100 mL of synthetic mineral water (SMW) with the addition of 7.5% (v/v) rice straw and corn cobs hydrolysate in Erlenmeyer flask. SMW used in this study was a modification from Pruthi and Cameotra (1997), the composition of SMW were 3.0 g/L (NH<sub>4</sub>)<sub>2</sub>SO<sub>4</sub>, 10 g/L NaCl, 0.2 g/L MgSO<sub>4</sub>·7H<sub>2</sub>O, 0.01 g/L CaCl<sub>2</sub>, 0.001 g/L MnSO<sub>4</sub>·H<sub>2</sub>O, 0.001 g/L H<sub>3</sub>BO<sub>3</sub>, 0.001 g/L ZnSO<sub>4</sub>·7H<sub>2</sub>O, 0.001 g/L CuSO<sub>4</sub>·5H<sub>2</sub>O, 0.005 g/L CoCl<sub>2</sub>·6H<sub>2</sub>O, 0.001 g/L NaMoO<sub>4</sub>·2H<sub>2</sub>O, 5 g/50 mL KH<sub>2</sub>PO<sub>4</sub>, 2.62047 g/50 mL K<sub>2</sub>HPO<sub>4</sub>, and 0.0006 g/50 mL Fe<sub>3</sub>SO<sub>4</sub>.

## 2.2. Rice straw and corn cobs hydrolysis by lignocellulolytic mold

*Penicillium citrinum* H9 spore was suspended in 10 mL sterile distilled water and measured their turbidity using spectrophotometer λ<sub>550 nm</sub> to get OD 0.5. After that, 4% (v/v) spore was added in Mandel Stenberg media and incubated for six days, with agitation 120 rpm. The hydrolysate concentration was measured using Somogyi-Nelson method. Rice straw and corn cobs hydrolysate components (glucose, sucrose and fructose) were identified using HPLC Agilent 1100 Series with auto-sampler, refractive index detector, Agilent Zorbax Carbohydrate column (4.6 × 150 mm, 5 μm), eluent acetonitril:distilled water (75:25) 1.4 mL/min at 30 °C, and sample inject volume 50 μL.

## 2.3. Identification of *Achromobacter* isolate using 16S rRNA analysis

Bacterial isolate stock was sub-cultured with three loops colonies in 20 mL of NB medium and incubated in room temperature with agitation of 120 rpm for 48 h. After incubation, isolate was extracted using CTAB method to get the DNA (Ausubel et al., 2003). Concentration and purity of the DNA was carried out using Multiskan GO on λ<sub>260 nm</sub> and λ<sub>280 nm</sub>. The DNA was mixed with the GoTaq Green Master Mix and 16S rRNA primers 518F (CCAGCAGCCGCGTAATACG) and 800R (TACCAGGG-TATCTAATCC), then it was amplified using Eppendorf Mastercycler. The conditions of the Polymerase Chain Reaction (PCR) were as follows: initial denaturation of 96 °C for 2 min, denaturation of 96 °C for 45 s, annealing of 51 °C for 30 s, elongation of 72 °C for 2 min, final elongation of 72 °C for 5 min, for 35 cycles. The amplicons were sequenced

and analysed their similarity with GenBank data using BLASTn NCBI (Altschul et al., 1997). MEGA 6.0 was used to analyze the distance and to construct the phylogenetic tree (Tamura et al., 2013).

## 2.4. Biosurfactant production from agricultural waste hydrolysate

*Achromobacter* sp. BP(1)5 was cultivated in nutrient broth for 24 h. It was measured the optical density until 0.5 at λ<sub>650 nm</sub>. Then, 2% (v/v) of bacterial culture was added on the SMW. Cultures were incubated for seven days with agitation of 120 rpm and temperature of 30 °C. The biosurfactant production was conducted in three replications. During the incubation, every day, the culture was quantified the growth condition, sugar concentration, and pH. After incubation, all cultures were separated between cell and supernatant with centrifugation at 6000 rpm. Precipitation of biosurfactant in the supernatant was carried out by adding of 6 N HCl (v/v) until pH 2 and incubated for a day in 4 °C. The supernatant was centrifuged at 6500 rpm to obtain crude biosurfactant.

## 2.5. Biosurfactant characterization

Crude biosurfactant was characterized by measuring the critical micelle concentration (CMC) and stability on pH, temperature and salinity, which based on surface tension value and emulsification activity. The CMC value was estimated through evaluation surface tension from crude biosurfactant at concentration 1 g/L to 10 g/L. CMC values were measured at 30 °C and at neutral pH 7. The biosurfactant stability test was done at pH 4, 7 and 10, temperature of 30 °C, 50 °C and 70 °C, and salinity of 0%, 5% and 10% (w/v).

## 3. Results and discussion

### 3.1. Hydrolysate product by *Penicillium citrinum* H9

Enzymatic hydrolysis of rice straw and corn cobs by *Penicillium citrinum* H9 for six days was successfully got 2.260 and 7.880 g/L of reducing sugar. Conversion efficiencies of agricultural waste into hydrolysate were 11.3% and 39.4%, respectively. Retention times of glucose, sucrose and fructose in chromatogram were 2.517, 2.776 and 2.487, respectively. Fig. 1 is chromatogram of rice straw and corn cobs hydrolysate, which the retention times were different from sugars standard. It showed that the type of sugar from rice straw and corn cob hydrolysate were not the third sugar. Meile et al. (2018) investigated the composition of sugars in wood hydrolysate using physical hydrolysis/autohydrolysis, the results showed that lignocellulase was largely converted to xylose.

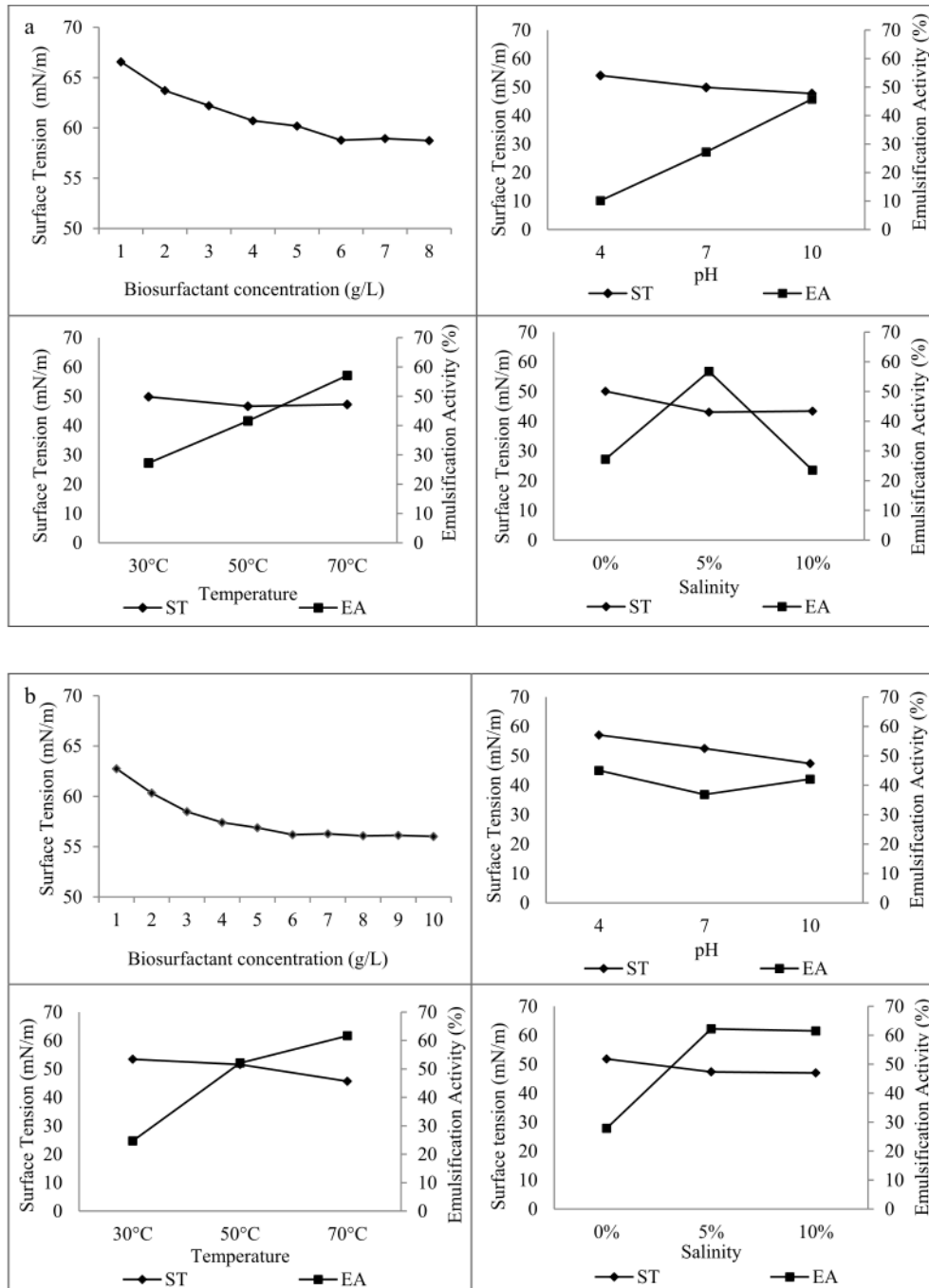


Fig. 4. Characters of *Achromobacter* sp. BP(1)5 biosurfactant on agricultural waste hydrolysis evaluated by Surface Tension (ST) and Emulsification Activity (EA) from different substrates (a) rice straw and (b) corn cobs.

### 3.2. *Achromobacter* sp. BP(1)5 identification based on 16S rRNA

*Achromobacter* sp. BP(1)5 was isolated from the Balongan oil sludge (Ni'matuzahroh et al., 2019a). Blast result of 16S rRNA identification approach was *Achromobacter xylosoxidans* IPA-CC9 (GenBank accession

no. MK875252) with query cover 98%. The sequence and some related references were analysed using distance method to construct phylogenetic tree (Fig. 2). In distance pair analysis (Fig. 2 (a)), *Achromobacter* sp. BP(1)5 had value 0.010 on taxon no. 7–12, that was genus *Achromobacter*. The lowest value of a distance pair indicates that it is a relative

**Table 1**  
Biosurfactant product of *Achromobacter* in various substrates.

Substrate	Production condition	Yield		CMC Concentration	Surface Tension	Stability	Reference
		Crude	Purified				
Corn cob SMW	pH 6.5, 7 days, shaker 120 rpm, 28 °C	0.1 g/L		6000 mg/L	56.2 mN/m	30-70 C pH 4-7 NaCl 0-10%	This study 20
Rice straw SMW	pH 6.5, 7 days, shaker 120 rpm, 28 °C	0.07 g/L		6000 mg/L	58.8 mN/m	30-70 C pH 4-7 NaCl 0-10%	This study 20
Glucose (1%) Yeast Extract (0.05%) MSM	pH 5.5-7.2, NaNO <sub>3</sub> (0.5%), 5 days, shaker 150 rpm, 30-37 °C		Rhamnolipid	81 mg/L	30.7 mN/m	20-100 C pH 2-12 NaCl 0-10%	Haloi and Medhi (2019) 5
Fermentation Medium (g/L): glycerine, 40; urea, 2; yeast extract, 1; KH <sub>2</sub> PO <sub>4</sub> , 1; Na <sub>2</sub> HPO <sub>4</sub> ·12H <sub>2</sub> O, 2; MgSO <sub>4</sub> ·7H <sub>2</sub> O, 0.2; NaCl, 10; and the trace element solution (1 ml/L)	150 rev/min, 6 days, 28 °C, pH 7.5	6.84 g/L	0.5 g/L Lipopeptide	48 mg/L	24.2 mN/m	40-100 C pH 6-12 NaCl 10-30 g/L	Deng et al. (2016) 6
Dextrose (3-4% w/v), C/N ratio 8.3 using sodium nitrate and beef extract, 2 × 10 <sup>5</sup> g equivalents Fe <sup>3+</sup> , 1500 mM PO <sub>4</sub> <sup>3-</sup> MSM	pH 7, 10 days, shaker 120 rpm, 30 °C		4.13 g/L rhamnolipid	136 mg/L	30.42 mN/m	30-121 C pH 6-12 0.5-5% w/v	Joy et al. (2019) 7

taxon, in contrast to the highest value is a distant taxon. Phylogenetic tree from Neighbor-Joining method (Fig. 2 (b)) showed that BP(1)5 is related with *Achromobacter* genera and Proteobacteria phylum. The nucleotide 16S rRNA of *Achromobacter* sp. BP(1)5 has been registered in GenBank with accession no. MN401689.

There are many bacteria that can produce biosurfactants, including groups of bacteria in the phylum of Actinobacteria, Firmicutes, and Proteobacteria. Although in the same phylum, each bacterium can produce different types of biosurfactants. The biosurfactant product from Actinobacteria phylum such as *Rhodococcus*, *Nocardia*, *Gordona*, *Mycobacterium*, *Corynebacterium*, and *Micrococcus*, are classified as trehalolipid, a glycolipid biosurfactant type (Kim et al., 2000; Franzetti et al., 2009; Tuleva et al., 2009; Ivanova et al., 2016; Dwivedi et al., 2019; Kuyukina and Ivshina, 2019). *Arthrobacter* produced arthrofactin, a lipopeptide biosurfactant type, and *Actinomyces* and *Streptomyces* that are still rare identified their biosurfactant type (Morikawa et al., 1993; Thampayak et al., 2008; Olajuyigbe and Ehiosun, 2016). Likewise with the Firmicutes phylum, biosurfactant from *Clostridium* has not been completely identified the type of biosurfactant, *Lactobacillus* was produced glycoprotein, a high molecule biosurfactant. *Bacillus* and *Staphylococcus* produces lipopeptide biosurfactant. (Cooper et al., 1980; Banat et al., 2010; Eddouaouda et al., 2012; Madhu and Prapulla, 2013). Bacteria in Proteobacteria phylum also produce biosurfactant. Biosurfactant from *Pseudomonas* and *Alcanivorax* are rhamnolipid (glycolipid biosurfactant type), and *Acinetobacter* produce emulsan and biodispersant (high molecule biosurfactant) (Rosenberg et al., 1988; Abraham et al., 1998; Lang and Wullbrandt, 1999; Banat et al., 2010; Ohadi et al., 2017). Burkholderiales order has some genus, for instance, *Burkholderia*, *Paraburkholderia*, *Bordetella*, and *Achromobacter* that have different biosurfactant product, which are rhamnolipid (glycolipid biosurfactant type) from *Burkholderia* and *Paraburkholderia*; lipopeptide and glycolipid biosurfactant type from *Achromobacter*; and unidentified biosurfactant from *bordetella* (Tavares et al., 2012; Odukkathil and Vasudevan, 2015; Deng et al., 2016; Joy et al., 2019).

Genomic of *Achromobacter* had revealed by Hong et al. (2017), from *Achromobacter* sp. HZ01 was found biosurfactant genes, which are LuxR family transcriptional regulator gene that important to synthesize glycolipid and one gene as non-ribosomal peptide synthetases that indicated to produce lipopeptide, then it proved by lipopeptide structure that got from *Achromobacter* sp. HZ01 (Deng et al., 2016). By those references, it can be estimated if *Achromobacter* sp. BP(1)5 can produce glycolipid and lipopeptide biosurfactants.

### 3.3. Production and characterization of *Achromobacter* sp. BP(1)5 biosurfactant

The growth of BP(1)5 increased on the first day and has entered the death phase on the 7th day of incubation. Based on Fig. 3, there is sugar utilization by BP(1)5 for its growth. Sugar concentration decreased from 1.010 g/L up to 0.223 g/L on corn cobs hydrolysate substrate and 0.611 g/L to 0.135 g/L on rice straw hydrolysate for 7 days incubation. The pH was measured during the incubation of BP(1)5 isolate. On the corn cobs hydrolysate substrate, the pH range of culture tends to be 5.0-6.0 and on the rice straw hydrolysate substrate 5.0-5.3.

Yañez-Ocampo et al. (2017) has found that the increasing sugar concentration in final day incubation of biosurfactant production by bacteria in cooking oil waste and coffee waste was inversely proportional with the first phase incubation that has low concentration. It was due to the bacteria produced glycolipid biosurfactant, which related with the biosurfactant product from *Achromobacter*. Consumption of sugar by bacteria was accompanied by the formation of biosurfactant products. Joy et al. (2019) stated that *Achromobacter* grown on MSM media with the addition of lignocellulosic-rice straw hydrolysate resulted in the amount of rhamnolipid which was almost similar to when the isolates grown on chemically defined medium which had a total-sugars composition 4.55% consist of glucose 2.8%, cellobiose 0.14%, xylose 1.5% %, and arabinose 0.11%. This shows that the composition of hydrolysate sugar of rice straw does not differ greatly from the composition of sugar in chemically defined media.

Biosurfactant product was harvested at 7th day, which products obtained as much as 0.074 g/L in rice straw hydrolysate and 0.095 g/L in corn cobs hydrolysate. Bioconversion percentages from rice straw and corn cobs hydrolysate into biosurfactants were 12.1% and 9.4% respectively. The percentages were not as good as expected. This can occur because the hydrolysate sugar is largely inaccessible to bacteria to be converted into biosurfactants. The main point of the result is *Achromobacter* sp. BP(1)5 can use low-cost substrate to produce biosurfactant, but further research is still needed to optimize hydrolysis of agricultural waste to obtain the most suitable substrate for biosurfactant production using *Achromobacter* sp. BP(1)5 and biosurfactant production of *Achromobacter* sp. BP(1)5.

The surface tension activity at critical micelle concentration value of corn cobs hydrolysate was lower than rice straw hydrolysate. CMC value on corn cobs hydrolysate substrate was 6 g/L with a surface tension reduction value of 56.2 mN/m, while CMC value on rice straw hydrolysate substrate was 6 g/L with a value of surface tension reduction of



58.8 mN/m. Fig. 4 shows the critical micelle concentration value and stability test on pH, temperature and salinity of biosurfactant product.

Biosurfactant of BP (1)5 still has activity to reduce surface tension and emulsification under pH 4.0–10.0, temperature 30 C–70 C, and salinity 0%–10% (w/v). The higher temperature, pH, and salinity tend to decrease surface tension activity, whereas the higher temperature and pH increase the emulsification activity value, the value of emulsification activity tends to decrease at salinity concentrations of more than 5% (w/v) on both substrates.

Measurement of the stability of biosurfactant products was carried out to determine the prospects for application of biosurfactant products. *Achromobacter* is known to be able to produce biosurfactants on various substrates. Table 1 is a comparison of biosurfactant data produced by *Achromobacter* by other researchers.

Agricultural wastes could be hydrolyzed into reducing sugars. The reducing sugars were converted by microbes into biosurfactant products. Biosurfactant production cost using the hydrolysate sugar substrate was hopefully cheaper than commercial sugar, but it still requires optimization of production conditions to obtain a greater yield. Based on Table 1, on different types of substrates, *Achromobacter* could produce different types of biosurfactants (glycolipids or lipopeptides), but the type of biosurfactant produced by *Achromobacter* sp. BP(1)5 have not been analysed yet. Further research is needed to reveal the types and coding genes of biosurfactants produced by *Achromobacter* sp. BP(1)5.

#### 4. Conclusion

The hydrolysate sugar of rice straw and corn cobs by *Penicillium citrinum* H9 could be converted to biosurfactants by *Achromobacter* sp. BP(1)5. Based on 16S rRNA analysis, *Achromobacter* sp. BP(1)5 had query cover 98% with *Achromobacter xylosoxidans*. Crude extract of *Achromobacter* sp. BP(1)5 biosurfactant produced on the hydrolysate substrate from rice straw and corn cobs had the same CMC value of 6.0 g/L with emulsification activity on kerosene 27.22% and 36.84% respectively. The biosurfactant crude extracts from both substrates were relative stable at variation of pH, temperature, and salinity.

#### Acknowledgments

This work was supported by the Ministry of Research, Technology and Higher Education Indonesia and Universitas Airlangga through Penelitian Unggulan Fakultas 2019 [grant no. 2444/UN3.1.8/LT/2019].

#### Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.bcab.2020.101534>.

#### References

- Abraham, W., Meyer, H., Yakimov, M., 1998. Novel glycine containing glucolipids from the alkene using bacterium *Alcanivorax borkumensis*. *Biochim. Biophys. Acta* 1393, 57–62. [https://doi.org/10.1016/S0005-2760\(98\)00058-7](https://doi.org/10.1016/S0005-2760(98)00058-7).
- Altschul, S.F., Madden, T.L., Schaffer, A.A., Zhang, J., Zhang, Z., Miller, W., Lipman, D.J., 1997. Gapped BLAST and PSIBLAST: a new generation of protein database search programs. *Nucleic Acids Res.* 25, 3389–3402. <https://doi.org/10.1093/nar/25.17.3389>.
- Austubel, F.M., Brent, R., Kingston, R.R., Moore, D.D., Seidman, J.G., Smith, J.A., Struhl, K., 2003. *Current Protocols in Molecular Biology*. John Wiley & Sons, Inc., New Jersey.
- Banat, I.M., Franzetti, A., Gandolfi, I., Bestetti, G., Martinotti, M.G., Fracchia, L., Smyth, T.J., Marchant, R., 2010. Microbial biosurfactants production, applications and future potential. *Appl. Microbiol. Biotechnol.* 87, 427–444. <https://doi.org/10.1007/s00253-010-2589-0>.
- Boonmee, A., 2012. Hydrolysis of various Thai agricultural biomasses using the crude enzyme from *Aspergillus aculeatus* Iizuka FR60 isolated from soil. *Braz. J. Microbiol.* 43, 456–466. <https://doi.org/10.1590/S1517-83822012000200005>.
- Cooper, D.G., Zajic, J.E., Gerson, D.F., Manninen, K.L., 1980. Isolation and identification of biosurfactants produced during anaerobic growth of *Clostridium pasteurianum*. *J. Ferment. Technol.* 56, 83–86. <http://ci.nii.ac.jp/naid/110002672519>.

- Das, A.J., Kumar, R., 2018. Utilization of agro-industrial waste for biosurfactant production under submerged fermentation and its application in oil recovery from sand matrix. *Bioresour. Technol.* 260, 233–240. <https://doi.org/10.1016/j.biortech.2018.03.093>.
- Deng, M.-C., Li, J., Hong, Y.-H., Xu, X.-M., Chen, W.-X., Yuan, J.-P., Peng, J., Yi, M., Wang, J.-H., 2016. Characterization of a novel biosurfactant produced by marine hydrocarbon-degrading bacterium *Achromobacter* sp. HZ01. *J. Appl. Microbiol.* 120, 889–899. <https://doi.org/10.1111/jam.13065>.
- Dos Reis, C.B.L., Morandini, L.M.B., Bevilacqua, C.B., Bublitz, F., Ugalde, G., Mazutti, M. A., Jacques, R.J.S., 2018. First report of the production of a potent biosurfactant with  $\alpha$ ,  $\beta$ -trehalose by *Fusarium fujikuroi* under optimized conditions of submerged fermentation. *Braz. J. Microbiol.* 49, 185–192. <https://doi.org/10.1016/j.bjm.2018.04.004>.
- Dwivedi, A., Kumar, A., Bhat, J.L., 2019. Production and characterization of biosurfactant from *Corynebacterium* species and its effect on the growth of petroleum degrading bacteria. *Microbiology* 88, 87–93. <https://doi.org/10.1134/S002626171901003X>.
- Eddououda, K., Mniif, S., Badis, A., Younes, S.B., Cherif, S., Ferhat, S., Mhiri, N., Chamkha, M., Sayadi, S., 2012. Characterization of a novel biosurfactant produced by *Staphylococcus* sp. strain 1E with potential application on hydrocarbon bioremediation. *J. Basic Microbiol.* 52, 408–418. <https://doi.org/10.1002/jobm.201100268>.
- Franzetti, A., Caredda, P., Colla, P.L., Pintus, M., Tamburini, E., Papacchini, M., Bestetti, G., 2009. Cultural factors affecting biosurfactant production by *Gordonia* sp. BS29. *Int. Biodeterior. Biodegrad.* 63, 943–947. <https://doi.org/10.1016/j.ibiod.2009.06.001>.
- Ghaffar, A., Yameen, M., Aslam, N., Jalal, F., Noreen, R., Munir, B., Mahmood, Z., Saleem, S., Rafiq, N., Falak, S., Tahir, I.M., Noman, M., Farooq, M.U., Qasim, S., Latif, F., 2017. Acidic and enzymatic saccharification of waste agricultural biomass for biotechnological production of xylitol. *Chem. Cent. J.* 11, 1–6. <https://doi.org/10.1186/s13065-017-0331-z>.
- Gomaa, E.Z., El-Melhy, R.M., 2019. Bacterial biosurfactant from *Citrobacter freundii* MG812314.1 as a bioremoval tool of heavy metals from wastewater. *Bull. Natl. Res. Cent.* 43, 69. <https://doi.org/10.1186/s42269-019-0088-8>.
- Halo, S., Medhi, T., 2019. Optimization and characterization of a glycolipid produced by *Achromobacter* sp. to use in petroleum industries. *J. Basic Microbiol.* 59 (3), 238–248. <https://doi.org/10.1002/jobm.201800298>.
- Helmy, Q., Kardena, E., Funamizu, N., Wisjuprpto, 2011. Strategies toward commercial scale of biosurfactant production as potential substitute for it chemically counterparts. *Int. J. Biotechnol.* 12, 66–86. <https://doi.org/10.1504/IJBT.2011.042682>.
- Hong, Y.-H., Ye, C.-C., Zhou, Q.-Z., Wu, X.-Y., Yuan, J.-P., Peng, J., Deng, H., Wang, J.-H., 2017. Genome sequencing reveals the potential of *Achromobacter* sp. HZ01 for bioremediation. *Front. Microbiol.* 8, 1507. <https://doi.org/10.3389/fmicb.2017.01507>.
- Ivanova, A.E., Sokolova, D.Sh., Kanat'eva, A.Yu., 2016. Hydrocarbon biodegradation and surfactant production by acidophilic mycobacteria. *Microbiology* 85, 317–324. <https://doi.org/10.1134/S002626171603005X>.
- Joy, S., Rahman, P.K.S.M., Khare, S.K., Sharma, S., 2019. Production and characterization of glycolipid biosurfactant from *Achromobacter* sp. (PS1) isolate using one-factor-at-a-time (OFAT) approach with feasible utilization of ammonia-soaked lignocellulosic pretreated residues. *Bioproc. Biosyst. Eng.* 42, 1301–1315. <https://doi.org/10.1007/s00449-019-02128-3>.
- Kim, S.H., Lim, E.J., Lee, S.O., Lee, J.D., Lee, T.H., 2000. Purification and characterization of biosurfactants from *Nocardia* sp. L-417. *Biotechnol. Appl. Chem.* 31, 249–253. <https://doi.org/10.1042/BA19990111>.
- Kuyukina, M.S., Ivshina, I.B., 2019. Production of trehalolipid biosurfactants by *Rhodococcus*. *Biology of Rhodococcus*. In: Alvarez, H. (Ed.), *Biology of Rhodococcus*, Microbiology Monographs. Springer, Cham., New York, pp. 271–298.
- Lang, M., Wullbrandt, D., 1999. Rhamnose lipids – biosynthesis, microbial production and application potential. *Appl. Microbiol. Biotechnol.* 51, 22–32. <https://doi.org/10.1007/s002530051358>.
- Madhu, A.N., Prapulla, S.G., 2013. Evaluation and functional characterization of a biosurfactant produced by *Lactobacillus plantarum* CFR 2194. *Appl. Biochem. Biotechnol.* <https://doi.org/10.1007/s12010-013-0649-5>.
- Mardawati, E., Andoyo, R., Syukra, K.A., Kresnowati, M.T.A.P., Bindar, Y., 2018. Production of xylitol from corn cob hydrolysate through acid and enzymatic hydrolysis by yeast. *IOP Conf. Ser. Earth Environ. Sci.* 141, 012019. <https://doi.org/10.1088/1755-1315/141/1/012019>.
- Martins, P.C., Martins, V.G., 2018. Biosurfactant production from industrial wastes with potential remove of insoluble paint. *Int. Biodeterior. Biodegrad.* 127, 10–16. <https://doi.org/10.1016/j.ibiod.2017.11.005>.
- Meile, K., Zhurinsk, A., Briede, L., Viksna, A., 2018. Investigation of the sugar content in wood hydrolysates with iodometric titration and UPLC-ELSD. *Agron. Res.* 16, 167–175. <https://doi.org/10.15159/ar.17.076>.
- Moldes, A.B., Torrado, A.M., Barral, M.T., Domínguez, J.M., 2007. Evaluation of biosurfactant production from various agricultural residues by *Lactobacillus pentosus*. *J. Agric. Food Chem.* 55, 4481–4486. <https://doi.org/10.1021/jf063075g>.
- Morikawa, M., Daido, H., Takao, T., Murata, S., Shimonishi, Y., Imanaka, T., 1993. A new lipopeptide biosurfactant produced by *Arthrobacter* sp. strain MIS38. *J. Bacteriol.* 20, 6459–6466. <https://doi.org/10.1128/jb.175.20.6459-6466.1993>.
- Moro, G.V., Almeida, R.T.R., Napp, A.P., Porto, C., Pilau, E.J., Lüdtké, D.S., Moro, A.V., Vainstein, M.H., 2018. Identification and ultra-high-performance-liquid chromatography coupled with high-resolution mass spectrometry characterization of biosurfactants including a new surfactin, isolated from oil-contaminated



- environments. *Microb. Biotechnol.* 11, 759–769. <https://doi.org/10.1111/1751-7915.13276>.
- Ni'matuzahroh, Sari, S.K., Ningrum, I.P., Pusfita, A.D., Marjayandari, L., Trikurniadewi, N., Ibrahim, S.N.M.M., Fatimah, Nurhariyati, T., Surtiningsih, T., Yuliani, H., 2019a. The potential of indigenous bacteria from oil sludge for biosurfactant production using hydrolysate of agricultural waste. *Biodiversitas* 20, 1374–1379. <https://doi.org/10.13057/biodiv/d200529>.
- Ni'matuzahroh, Sari, S.K., Trikurniadewi, N., Pusfita, A.D., Ningrum, I.P., Ibrahim, S.N.M.M., Fatimah, Surtiningsih, T., 2019b. Utilization of rice straw hydrolysis product of *Penicillium* sp. H9 as a substrate of biosurfactant production by LII61 hydrocarbonoclastic bacteria. *IOP Conf. Ser. Earth Environ. Sci.* 217, 012028. <https://doi.org/10.1088/1755-1315/217/1/012028>.
- Nwaguma, I.V., Chikere, C.B., Okpokwasili, G.C., 2016. Isolation, characterization, and application of biosurfactant by *Klebsiella pneumoniae* strain ivn51 isolated from hydrocarbon-polluted soil in Ogoniland, Nigeria. *Bioresour. Bioprocess.* 3, 40. <https://doi.org/10.1186/s40643-016-0118-4>.
- Odukkathil, G., Vasudevan, N., 2015. Biodegradation of endosulfan isomers and its metabolite endosulfate by two biosurfactant producing bacterial strains of *Bordetella pertussis*. *J. Environ. Sci. Health - Part B Pesticides, Food Contam. Agric. Wastes* 50, 81–89. <https://doi.org/10.1080/03601234.2015.975596>.
- Ohadi, M., Dehghan-Noudeh, G., Shakibaie, M., Banat, I.M., Pournamdar, M., Forootanfar, H., 2017. Isolation, characterization, and optimization of biosurfactant production by an oildegrading *Acinetobacter junii* B6 isolated from an Iranian oil excavation site. *Biocatal. Agric. Biotechnol.* <https://doi.org/10.1016/j.beab.2017.08.007>.
- Olajuyigbe, F.M., Ehiusun, K.I., 2016. Assessment of crude oil degradation efficiency of newly isolated actinobacteria reveals untapped bioremediation potentials. *Ann. Finance* 20, 133–143. <https://doi.org/10.1080/1088.9868.2015.1113926>.
- Pele, M.A., Ribeaux, D.R., Vieira, E.R., Souza, A.F., Luna, M.A.C., Rodríguez, D.M., Andrade, R.F.S., Alviano, D.S., Alviano, C.S., Barreto-Bergter, E., Santiago, A.L.C.M.A., Campos-Takaki, G.M., 2019. Conversion of renewable substrates for biosurfactant production by *Rhizopus arrhizus* UCP 1607 and enhancing the removal of diesel oil from marine soil. *Electron. J. Biotechnol.* 38, 40–48. <https://doi.org/10.1016/j.ejbt.2018.12.003>.
- Pruthi, V., Cameotra, 1997. Rapid identification of biosurfactant producing bacterial strain using cell surface hydrophobicity techniques. *Biotechnol. Tech.* 11, 671–674. <https://doi.org/10.1023/A:1018411427192>.
- Qiao, N., Shao, Z., 2010. Isolation and characterization of a novel biosurfactant produced by hydrocarbon-degrading bacterium *Alcalivarax dieselolei* B-5. *J. Appl. Microbiol.* 108, 1207–1216. <https://doi.org/10.1111/j.1365-2672.2009.04513.x>.
- Rosenberg, E., Rubinovitz, C., Legmann, R., Ron, E.Z., 1988. Purification and chemical properties of *Acinetobacter calcoaceticus* A2 biodispersant. *Appl. Environ. Microbiol.* 54, 323–326.
- Shawky, B.T., Mahmoud, M.G., Ghazy, E.A., Asker, M.M.S., Ibrahim, G.S., 2011. Enzymatic hydrolysis of rice straw and corn stalks for monosugars production. *J. Genet. Eng. Biotechnol.* 9, 59–63. <https://doi.org/10.1016/j.jgeb.2011.05.001>.
- Subagya, E.H., Iswadi, Noorjenah, Poerwaningsih, R., Drajat, D., Slagian, S.H., Hartini, M., Fitrianingrum, V., Kadir, Anggraeny, R., Amalia, R.R., Lestari, N.G.P.A., Prasetyo, O.R., 2016. *Produksi Tanaman Pangan Angka Tetap Tahun 2015*. Badan Pusat Statistik, Jakarta.
- Sunarti, T.C., Meryandini, A., Sofiyanto, M.E., Richana, N., 2010. Saccharification of comcob using cellulolytic bacteria for bioethanol production. *BIOTROPIA* 17, 105–115. <http://journal.biotrop.org/index.php/biotropia/article/view/80/57>.
- Tamura, K., Stecher, G., Peterson, D., Filipski, A., Kumar, S., 2013. MEGA6: molecular evolutionary genetics analysis version 6.0. *Mol. Biol. Evol.* 30, 2725–2729. <https://doi.org/10.1093/molbev/mst197>.
- Tavares, L.F.D., Silva, P.M., Junqueira, M., Mariano, D.C.O., Nogueira, F.C.S., Domont, G.B., Freire, D.M.G., Neves, B.C., 2012. Characterization of rhamnolipids produced by wild-type and engineered *Burkholderia kururiensis*. *Biotechnol. Prod. Process. Eng.* 97, 1909–1921. <https://doi.org/10.1007/s00253-012-4454-9>.
- Thampayak, I., Cheeptham, N., Pathom-Aree, W., Leelapornpisid, P., Lumyong, S., 2008. Isolation and identification of biosurfactant producing actinomycetes from soil. *Res. J. Microbiol.* 7, 499–507. <https://doi.org/10.3923/jm.2008.499.507>.
- Tuleva, B., Christova, N., Cohen, R., Antonova, D., Todorov, T., Stoineva, I., 2009. Isolation and characterization of trehalose tetraester biosurfactants from a soil strain *Micrococcus luteus* BN56. *Process Biochem.* 44, 135–141. <https://doi.org/10.1016/j.procbio.2008.09.016>.
- Yañez-Ocampo, G., Somoza-Coutiño, G., Blanco-Gonzalez, C., Wong-Villarreal, A., 2017. Utilization of agroindustrial waste for biosurfactant production by native bacteria from Chiapas. *Open Agric.* 2, 341–349. <https://doi.org/10.1515/opag-2017-0038>.

# Bioconversion of agricultural waste hydrolysate from lignocellulolytic mold into biosurfactant by *Achromobacter* sp. BP(1)5

---

## ORIGINALITY REPORT

---

17%

SIMILARITY INDEX

10%

INTERNET SOURCES

15%

PUBLICATIONS

6%

STUDENT PAPERS

---

## PRIMARY SOURCES

---

- |   |  |    |
|---|--|----|
| 1 | Submitted to Universitas Airlangga<br>Student Paper  | 2% |
| 2 | Ni'matuzahroh, S K Sari, N Trikurniadewi, A D Pusifita, I P Ningrum, S N M M Ibrahim, T Nurhariyati, Fatimah, T Surtiningsih. " Utilization of Rice Straw Hydrolysis Product of sp. H9 as A Substrate of Biosurfactant Production by LII61 Hydrocarbonoclastic Bacteria ", IOP Conference Series: Earth and Environmental Science, 2019<br>Publication | 2% |
| 3 | Submitted to Universitas Brawijaya<br>Student Paper  | 1% |
| 4 | <a href="http://www.waset.org">www.waset.org</a><br>Internet Source  | 1% |
| 5 | <a href="http://d-nb.info">d-nb.info</a><br>Internet Source  | 1% |
-

6	<p>Alif Chebbi, Massimiliano Tazzari, Cristiana Rizzi, Franco Hernan Gomez Tovar et al. "Burkholderia thailandensis E264 as a promising safe rhamnolipids' producer towards a sustainable valorization of grape marcs and olive mill pomace", Applied Microbiology and Biotechnology, 2021</p> <p>Publication</p>	1 %
7	<p>Femina Carolin C, P. Senthil Kumar, P. Tsopbou Ngueagni. "A Review on New Aspects of Lipopeptide Biosurfactant: Types, Production, Properties and its Application in the Bioremediation Process", Journal of Hazardous Materials, 2020</p> <p>Publication</p>	1 %
8	<p><a href="http://www.alice.cnptia.embrapa.br">www.alice.cnptia.embrapa.br</a></p> <p>Internet Source</p>	1 %
9	<p>Submitted to Minnesota State University, Mankato</p> <p>Student Paper</p>	1 %
10	<p><a href="http://researchportal.port.ac.uk">researchportal.port.ac.uk</a></p> <p>Internet Source</p>	1 %
11	<p>Submitted to University of Central Lancashire</p> <p>Student Paper</p>	1 %
12	<p>"Biosurfactants for a Sustainable Future", Wiley, 2021</p> <p>Publication</p>	1 %

13	sfamjournals.onlinelibrary.wiley.com Internet Source	<1 %
14	"Biosurfactants", Springer Science and Business Media LLC, 2010 Publication	<1 %
15	Handbook of Hydrocarbon and Lipid Microbiology, 2010. Publication	<1 %
16	f1000research.com Internet Source	<1 %
17	Arun Singh Pathania, Asim Kumar Jana. "Improvement in Production of Rhamnolipids Using Fried Oil with Hydrophilic Co-substrate by Indigenous Pseudomonas aeruginosa NJ2 and Characterizations", Applied Biochemistry and Biotechnology, 2020 Publication	<1 %
18	Sam Joy, Pattanathu K. S. M. Rahman, Sunil K. Khare, Shashi Sharma. "Production and characterization of glycolipid biosurfactant from Achromobacter sp. (PS1) isolate using one-factor-at-a-time (OFAT) approach with feasible utilization of ammonia-soaked lignocellulosic pretreated residues", Bioprocess and Biosystems Engineering, 2019 Publication	<1 %
19	Microbiology Monographs, 2011.	



20

Francieli Dalcanton, Elena Carrasco, Fernando Pérez-Rodríguez, Guiomar Denisse Posada-Izquierdo et al. " Modeling the Combined Effects of Temperature, pH, and Sodium Chloride and Sodium Lactate Concentrations on the Growth Rate of ATCC 8014 ", Journal of Food Quality, 2018

Publication

<1 %

21

"Advances in the Domain of Environmental Biotechnology", Springer Science and Business Media LLC, 2021

Publication

<1 %

22

Abdel-Aziz, Al-Omar, Mohammed, Emam. "In Vitro and Ex Vivo Antibiofilm Activity of a Lipopeptide Biosurfactant Produced by the Entomopathogenic Beauveria bassiana Strain against Microsporium canis", Microorganisms, 2020

Publication

<1 %

23

Kazumasa Fukuda, Sumio Nagata, Hatsumi Taniguchi. "Isolation and characterization of dibenzofuran-degrading bacteria", FEMS Microbiology Letters, 2002

Publication

<1 %

24

[bbrc.in](http://bbrc.in)  
Internet Source

<1 %

---

25

Chikodili G. Anaukwu, Chioma M. Ogbukagu, Ikechukwu A. Ekwealor. "Optimized Biosurfactant Production by *Pseudomonas aeruginosa* Strain CGA1 Using Agro-Industrial Waste as Sole Carbon Source", *Advances in Microbiology*, 2020

Publication

---

<1 %

26

Glaci V. Moro, Rafaela T.R. Almeida, Amanda P. Napp, Carla Porto et al. "Identification and ultra-high-performance liquid chromatography coupled with high-resolution mass spectrometry characterization of biosurfactants, including a new surfactin, isolated from oil-contaminated environments", *Microbial Biotechnology*, 2018

Publication

---

<1 %

27

Valéria Ortaça Portela, Anderson Moro, Natielo Almeida Santana, Daiana Bortoluzzi Baldoni et al. " FIRST REPORT ON THE PRODUCTION OF PHYTOTOXIC METABOLITES BY UNDER OPTIMIZED CONDITIONS OF SUBMERGED FERMENTATION ", *Environmental Technology*, 2020

Publication

---

<1 %

28

Brumano, Larissa Pereira, Matheus Francisco Soler, and Silvio Silvério da Silva. "Recent Advances in Sustainable Production and Application of Biosurfactants in Brazil and

<1 %

Latin America", Industrial Biotechnology,  
2016.

Publication

---

29

Deepansh Sharma, Anita Saini.

"Lignocellulosic Ethanol Production from a Biorefinery Perspective", Springer Science and Business Media LLC, 2020

Publication

---

<1 %

30

Omid Moradi, Samira Mhdavi, Sajjad

Sedaghat. "Synthesis and Characterization of Chitosan/Agar/SiO<sub>2</sub> Nano Hydrogels For Removal of Amoxicillin and of Naproxen From Pharmaceutical Contaminants", Research Square, 2021

Publication

---

<1 %

31

Ratan Singh, Sanjeev Kumar Singh, Dheeraj

Rathore. "Analysis of biosurfactants produced by bacteria growing on textile sludge and their toxicity evaluation for environmental application", Journal of Dispersion Science and Technology, 2019

Publication

---

<1 %

32

Zhenming Yu, Chunmei He, Jaime A. Teixeira

da Silva, Guihua Zhang, Wei Dong, Jianping Luo, Jun Duan. "Molecular cloning and functional analysis of DoUGE related to water-soluble polysaccharides from *Dendrobium officinale* with enhanced abiotic stress

<1 %

# tolerance", Plant Cell, Tissue and Organ Culture (PCTOC), 2017

Publication

33

[preview-www.springeropen.com](http://preview-www.springeropen.com)

Internet Source

<1 %

34

[worldwidescience.org](http://worldwidescience.org)

Internet Source

<1 %

35

[www.freepatentsonline.com](http://www.freepatentsonline.com)

Internet Source

<1 %

36

[www.granthaalayahpublication.org](http://www.granthaalayahpublication.org)

Internet Source

<1 %

37

Seng Hon Kee, Justin Brian V. Chiongson, Jonel P. Saludes, Sevakumaran Vigneswari, Seeram Ramakrishna, Kesaven Bhubalan.

"Bioconversion of agro-industry sourced biowaste into biomaterials via microbial factories – A viable domain of circular economy", Environmental Pollution, 2021

Publication

<1 %

38

"Sustainable Green Chemical Processes and their Allied Applications", Springer Science and Business Media LLC, 2020

Publication

<1 %

39

[hdl.handle.net](http://hdl.handle.net)

Internet Source

<1 %



---

Exclude quotes Off

Exclude matches Off

Exclude bibliography On

# Bioconversion of agricultural waste hydrolysate from lignocellulolytic mold into biosurfactant by *Achromobacter* sp. BP(1)5

---

GRADEMARK REPORT

---

FINAL GRADE

**/0**

GENERAL COMMENTS

**Instructor**

---

PAGE 1

---

PAGE 2

---

PAGE 3

---

PAGE 4

---

PAGE 5

---

PAGE 6

---

PAGE 7

---

PAGE 8

---