



Innovative Scientific Information & Services Network  
Sharing innovative sciences

Open-Access Publisher

Serving the world wide scientific community since 2004 ----- Bioscience Research is in 15th year of publication ----- Bioscience Research on Scimago Journal & Country Rank powered by Scopus -- IPP = 0.55, SNIPP=0.949, h index = 4, Rank = Q4

BOOKS JOURNALS PUBLISHER FOR AUTHORS SUBMIT ARTICLE

## QUICK LINKS

- [Home](#)
- [about us](#)
- [Author guidelines](#)
- [Authorship Policy](#)
- [Copyrights](#)
- [Review process](#)
- [Submission](#)

## Call for papers



Bioscience Research  
(ISSN: 1811-9506)  
Science 2004



Animal Science Journal



Plant Science Journal

Hit Counter

**Bioscience Research****Bioscience Research**

- Print ISSN: 1811-9506
- Online ISSN: 2218-3973
- Starting year: 2004
- Current volume: 15
- Editor-in-chief: Dr. Z. H. Malik

- [Author guidelines](#)
- [Editorial board](#)
- [All vols & issues](#)
- [Indexing & coverage](#)

Bioscience Research, volume 15, issue 2 (April-June), 2018

| Sr. # | Titles, Authors & affiliation (s)  |   |             | Download                             |
|-------|--|---|-------------|--------------------------------------|
|       | <b>Research Articles</b>   |   |             |                                      |
| 1     | RESEARCH ARTICLE   | BIOSCIENCE RESEARCH, 2018 15(2): 549-564. | OPEN ACCESS | <a href="#">Free Full text [PDF]</a> |
|       | <b>Effect of nitrogen, phosphorus and potassium nano fertilizers with different application times, methods and rates on some growth parameters of Egyptian cotton (<i>Gossypium barbadense</i> L.)</b> |   |             |                                      |
|       | <b>Eleyan Sohair E.D, Abodahab Abdall A, Abdallah Amany M and Rabeh Houda A.*</b>  |   |             |                                      |
|       | Department of Agronomy, Fac. of Agric., Cairo Univ., Giza, Egypt.  |   |             |                                      |
| 2     | RESEARCH ARTICLE   | BIOSCIENCE RESEARCH, 2018 15(2): 565-574. | OPEN ACCESS | <a href="#">Free Full text [PDF]</a> |
|       | <b>Comparative Impacts of Salt Stress on Survival and Leaf Anatomy Traits in Olive Genotypes</b>   |   |             |                                      |
|       | <b>Fayek M.A.<sup>1</sup> Fayed T.A.<sup>1</sup>, Emtithal H. El-Sayed<sup>2</sup>, Ebtesam E. Abd El-Hameed<sup>2</sup></b>   |   |             |                                      |
|       | <sup>1</sup> Pomology Department, Faculty of Agriculture, Cairo University, Giza, Egypt.   |   |             |                                      |
|       | <sup>2</sup> Olive & Semi-Arid Zone Fruits, Agriculture Research Center, Horticulture Research Institute, Giza, Egypt.   |   |             |                                      |
| 3     | RESEARCH ARTICLE   | BIOSCIENCE RESEARCH, 2018 15(2): 575-588. | OPEN ACCESS | <a href="#">Free Full text [PDF]</a> |
|       | <b>Influence of gamma rays, humic acid and sodium nitroprusside on growth, chemical constituents and fruit quality of snap bean plants under different soil salinity levels</b>                        |   |             |                                      |
|       | <b>A.H. Hanafy Ahmed<sup>1</sup>; Hanaa F.Y. Mohamed<sup>1</sup>; I.O.A. Orabi<sup>2</sup> and A.M. El-Hefny<sup>2</sup></b>   |   |             |                                      |
|       | <sup>1</sup> Plant Physiology Section, Faculty of Agriculture, Cairo University Egypt  |   |             |                                      |
|       | <sup>2</sup> Department of Natural Products, National Center for Radiation Research and Technology, Nasr City, Cairo, Egypt  |   |             |                                      |
| 4     | RESEARCH ARTICLE   | BIOSCIENCE RESEARCH, 2018 15(2): 589-601. | OPEN ACCESS | <a href="#">Free Full text [PDF]</a> |
|       | <b>Response of Apple Seedlings Grown Under Saline Conditions to Natural Plant Extracts</b>   |   |             |                                      |
|       | <b>Rania Ahmed Mahmoud<sup>1</sup> and Abeer Aly Dahab<sup>2</sup></b>   |   |             |                                      |
|       | <sup>1</sup> Deciduous Fruit Research Department, Horticulture Research Institute, Agricultural Research Center, Egypt.  |   |             |                                      |
|       | <sup>2</sup> Medicinal and Aromatic Plants Research Department, Horticulture Research Institute, Agricultural Research Center, Egypt   |   |             |                                      |
| 5     | RESEARCH ARTICLE   | BIOSCIENCE RESEARCH, 2018 15(2): 602-609. | OPEN ACCESS | <a href="#">Free Full text [PDF]</a> |
|       | <b>Occurrence of lettuce Fusarium wilt caused by <i>Fusarium oxysporum</i> f. sp. <i>lactucae</i> in Egypt and its management by using solarization, metam sodium and certain of bioproducts</b>       |   |             |                                      |
|       | <b>El-Sayed S. Fathy<sup>1</sup>; Nour El-Houda A. Reyad<sup>2</sup>; Ahmed A.<sup>1</sup> and Amr M. Hanafy<sup>1</sup></b>   |   |             |                                      |

- <sup>1</sup>Vegetables Crops Dept., Faculty of Agriculture, Cairo University, 12316, Egypt  
<sup>2</sup>Plant Pathology Dept., Faculty of Agriculture, Cairo University, 12316, Egypt
- 6 RESEARCH ARTICLE BIOSCIENCE RESEARCH, 2018 15(2): 610-617. OPEN ACCESS [Free Full text \[PDF\]](#)
- Effect of soft tissues manipulation on patients with chronic bronchitis**
- El Sayed Atwa Hanoura<sup>1</sup>, Akram Abd El Aziz Sayed<sup>2</sup>, Awny Foad Rahmy<sup>2</sup>, Mohammed Sayed Hanter<sup>3</sup>, Mohammed Abd El Halim Mohammed Shendy<sup>2</sup>
- <sup>1</sup>Faculty of Physical Therapy, Kafr Elshikh University, Egypt  
<sup>2</sup>Faculty of Physical Therapy, Cairo University, Egypt  
<sup>3</sup>Faculty of Medicine, Tanta University, Egypt
- 7 RESEARCH ARTICLE BIOSCIENCE RESEARCH, 2018 15(2): 618-627. OPEN ACCESS [Free Full text \[PDF\]](#)
- Growth and Quality of *Spathiphyllum wallisii* L. Plants as Affected by Foliar Sprays of Algae, Chitosan, Atonik and Humic Acid**
- El-Khateeb M.A., A.E. El-Madaawy and A.A. Saber
- Department of Ornamental Horticulture, Faculty of Agriculture, Cairo University, Giza, Egypt.
- 8 RESEARCH ARTICLE BIOSCIENCE RESEARCH, 2018 15(2): 628-636. OPEN ACCESS [Free Full text \[PDF\]](#)
- Response of *Silybium marianum* L. plants to foliar application of algae, chitosan and effective microorganisms.**
- El-Khateeb M.A., El-Attar A.B. and R.G. Fayed
- Department of Ornamental Horticulture, Faculty of Agriculture, Cairo University, Giza, Egypt
- 9 RESEARCH ARTICLE BIOSCIENCE RESEARCH, 2018 15(2): 637-644. OPEN ACCESS [Free Full text \[PDF\]](#)
- Response of broiler chicks to diets supplemented with *Moringa Oleifera* dry leaves and some antioxidants under tropical summer conditions**
- Ahmed Gouda, Mosaad Mohamed El-Moniary, Amani Wagih Youssef, Yasser Hamouda, Hussein Mohamed Ahmed Hassan, and Eman Farag El-Daly
- Department of Animal Production, National Research Centre, 12622, Dokki, Egypt
- 10 RESEARCH ARTICLE BIOSCIENCE RESEARCH, 2018 15(2): 645-654. OPEN ACCESS [Free Full text \[PDF\]](#)
- Nano and Mineral Selenium Foliar Application Effect on Pea Plants (*Pisum sativum* L.)**
- Shaymaa Ismail Shedeed<sup>1</sup>, Zakaria Fouad Fawzy<sup>2\*</sup> and Abd El-Mohsin Mahmoud El-Bassiony<sup>2</sup>
- <sup>1</sup>Plant Nutrition Department, National Research Centre, Cairo, Egypt  
<sup>2</sup>Veg. Res. Dept., National Research Centre, Cairo, Egypt.
- 11 RESEARCH ARTICLE BIOSCIENCE RESEARCH, 2018 15(2): 655-662. OPEN ACCESS [Free Full text \[PDF\]](#)
- In vitro* shoot regeneration of tembesu (*Fagraea fragrans* Roxb.) from seed explants on different concentrations of sucrose and honey**
- Siti Fatonah and Mayta Novaliza Isda
- Biology Department, Faculty of Mathematics and Natural Sciences, Universitas Riau, Indonesia.
- 12 RESEARCH ARTICLE BIOSCIENCE RESEARCH, 2018 15(2): 663-671. OPEN ACCESS [Free Full text \[PDF\]](#)
- Effects of soil texture and burial depth on the biological parameters of overwintering pupae of *Bactrocera oleae* (Diptera:Tephritidae)**
- Bachouche N<sup>1,3</sup>, Kellouche A<sup>1,2</sup> and et Lamine S<sup>3,4</sup>
- <sup>1</sup>Laboratoire de Production, Protection des Espèces Menacées et des Récoltes. Influence des variations Climatiques. Université Mouloud MAMMERI, Tizi-Ouzou Algeria  
<sup>2</sup>Faculty of Biological sciences and Agronomic sciences, Mouloud MAMMERI University, 15000, Tizi-Ouzou, Algeria  
<sup>3</sup>Faculty of Natural Sciences, Life and Earth Sciences, University Akli Mohand Oulhadj of Bouira, 10000, Bouira, Algeria  
<sup>4</sup>Department of Geography and Earth Sciences, University of Aberystwyth, Ceredigion SY23 3DB, Wales, United Kingdom.
- 13 RESEARCH ARTICLE BIOSCIENCE RESEARCH, 2018 15(2): 672-682. OPEN ACCESS [Free Full text \[PDF\]](#)
- Genetic Fingerprinting of Harid Fish (*Scarus arabicus*) and Molecular Characterization of some pathogenic Bacterial Isolates from fish Viscera in Saudi Arabia**
- Emad A. Mahdi<sup>1,2</sup>, Mohamed M. Hassan<sup>1,3\*</sup>, Ebied, M. Abdelbasit<sup>1,4</sup>, Ahmed Gaber<sup>1,5</sup> and Fathy M.

Abd-Elghany<sup>6</sup><sup>1</sup>Department of Biological Science, Faculty of Science, Taif University, Saudi Arabia.<sup>2</sup>Department of Zoology, Faculty of Science, South Valley University, Egypt.<sup>3</sup>Department of Genetics, Faculty of Agriculture, Minufiya University, Egypt.<sup>4</sup>Department of Pathology, Faculty of Veterinary Medicine, Beni Suef University, Egypt.<sup>5</sup>Department of Genetics, Faculty of Agriculture, Cairo University, Egypt.<sup>6</sup>Department of Animal Production, Fish Production, Faculty of Agriculture, Al-Azhar University, Cairo, Egypt.

14 RESEARCH ARTICLE BIOSCIENCE RESEARCH, 2018 15(2): 683-693. OPEN ACCESS

Free Full text  
[PDF]**Multiple-response optimization of the acidic pre-treatment of the brown alga *Sargassum cristaefolium* for the alginate extraction using twin screw extruder**Sugiono Sugiono<sup>1,2</sup>, Masruri Masruri<sup>3</sup>, Teti Estiasih<sup>4</sup> and Simon Bambang Widjanarko<sup>4</sup><sup>1</sup>Doctoral Degree of Agricultural Product Technology, Faculty of Agriculture, Brawijaya University, Malang 65145, Indonesia<sup>2</sup>Department of Fisheries Science, Faculty of Agriculture, Madura Islamic University- Pamekasan 69351, Indonesia<sup>3</sup>Department of Chemistry – Faculty of Sciences – Brawijaya University – Malang- 65145, Indonesia<sup>4</sup>Department of Food Science and Technology – Faculty of Agricultural Technology – Brawijaya University Malang, 65145, Indonesia

15 RESEARCH ARTICLE BIOSCIENCE RESEARCH, 2018 15(2): 694-701. OPEN ACCESS

Free Full text  
[PDF]**Direct and indirect selection of plant maturity component of some soybean genotypes resistant to leaf rust disease**Mohammad Setyo Poerwoko<sup>1</sup> and Nurul Sjamsijah<sup>2</sup><sup>1</sup>Agronomy Study Program, Plant Breeding Specialist, Agriculture Faculty, Jember University Kalimantan Street 37, Tegai Boto Campuss, Jember 68121 East of Java, Indonesia.<sup>2</sup>Seed Technology Study Programme, Jember State of Polytechnic of Agriculture Jember, Mastrap Street PO Box 164 Jember 68121 Indonesia.

16 RESEARCH ARTICLE BIOSCIENCE RESEARCH, 2018 15(2): 702-707. OPEN ACCESS

Free Full text  
[PDF]**The protective efficacy of locally prepared combined inactivated *Mycoplasma gallisepticum* and *Pasteurella multocida* vaccine in chickens**\*Fatma F. Ibrahim<sup>1</sup>, Wafaa A. Abd El-Ghany<sup>2</sup>, Eman M. El Rawy<sup>1</sup>, Mona M. Shaker<sup>3</sup> and El-Jakee J<sup>2</sup>.<sup>1</sup>Veterinary Serum and Vaccine Research Institute, Abbasia, Cairo, Egypt<sup>2</sup>Faculty of Veterinary Medicine, Cairo University, Cairo, Egypt<sup>3</sup>Animal Health Research Institute, Dokki, Giza, Egypt

17 RESEARCH ARTICLE BIOSCIENCE RESEARCH, 2018 15(2): 708-715. OPEN ACCESS

Free Full text  
[PDF]**Aerobic versus resistive training on selected hematological parameters in elderly**Mona Ahmed Mohamed Abd El Wahab<sup>1,\*</sup>, Hala Mohamed Ezz Eldin<sup>1</sup>, Aisha Abdel Monem Hagag<sup>1</sup> and Shawky Abd Elhamid Fouad<sup>2</sup><sup>1</sup>Faculty of Physical Therapy, Cairo University, Egypt.<sup>2</sup>Faculty of Medicine, Cairo University, Egypt

18 RESEARCH ARTICLE BIOSCIENCE RESEARCH, 2018 15(2): 716-730. OPEN ACCESS

Free Full text  
[PDF]**Growth, flowering and chemical compositions of *Tagetes patula* L. plants as affected with naphthalene acetic acid and gibberellic acid.**Amira K. G. Atteya<sup>1\*</sup> and Abd El-Nasser G. El Gendy<sup>2</sup><sup>1</sup>Horticulture Department, Faculty of Agricultural, Damanhour University, Egypt.<sup>2</sup>Medicinal and Aromatic Plants Research Department, National Research Centre, Dokki, 12622, Cairo, Egypt

19 RESEARCH ARTICLE BIOSCIENCE RESEARCH, 2018 15(2): 731-743. OPEN ACCESS

Free Full text  
[PDF]**Tomato (*Lycopersicon esculentum*, Mill.) Performance and Yield on Plantation Patterns Variations and Irrigation Techniques**

Olivina S. Messakh, Jemrifs H.H. Sonbai and Laurensius Lehar

Department of Food Crops and Horticulture, State Agricultural Polytechnic of Kupang, Indonesia.

20 RESEARCH ARTICLE BIOSCIENCE RESEARCH, 2018 15(2): 744-753. OPEN ACCESS

Free Full text  
[PDF]**Peroxidase isozyme from rice in M<sub>1</sub> generation under drought stress**Bagus Herwibawa<sup>1\*</sup>, Sakhidin<sup>2</sup> and Totok Agung Dwi Haryanto<sup>2</sup><sup>1</sup>Laboratory of Physiology and Crop Breeding, Faculty of Animal and Agricultural Sciences, Diponegoro University, Tembalang Campus, Semarang 50275, Central Java, Indonesia.

# Multiple-response optimization of the acidic pretreatment of the brown alga *Sargassum cristaeifolium*

*by* Sugiono Sugiono

---

**Submission date:** 18-Dec-2021 02:41PM (UTC+0700)

**Submission ID:** 1733298222

**File name:** cidic\_pretreatment\_of\_the\_brown\_alga\_Sargassum\_cristaeifolium.pdf (847.48K)

**Word count:** 6066

**Character count:** 31795



7 Available online freely at [www.isisn.org](http://www.isisn.org)

# Bioscience Research

Print ISSN: 1811-9506 Online ISSN: 2218-3973

Journal by Innovative Scientific Information & Services Network



RESEARCH ARTICLE

BIOSCIENCE RESEARCH, 2018 15(2): 683-693.

OPEN ACCESS

## Multiple-response optimization of the acidic pre-treatment of the brown alga *Sargassum cristaefolium* for the alginate extraction using twin screw extruder

Sugiono Sugiono<sup>1,2</sup>, Masruri Masruri<sup>3</sup>, Teti Estiasih<sup>4</sup> and Simon Bambang Widjanarko<sup>4</sup>

<sup>1</sup>Doctoral Degree of Agricultural Product Technology, Faculty of Agriculture, Brawijaya University, Malang 65145, Indonesia

<sup>2</sup>Department of Fisheries Science, Faculty of Agriculture, Madura Islamic University- Pamekasan 69351, Indonesia

<sup>3</sup>Department of Chemistry – Faculty of Sciences – Brawijaya University – Malang- 65145, Indonesia

<sup>4</sup>Department of Food Science and Technology – Faculty of Agricultural Technology – Brawijaya University Malang, 65145, Indonesia

\*Correspondence: [yonosugiono78@yahoo.co.id](mailto:yonosugiono78@yahoo.co.id) Accepted: 07 May 2018 Published online: 22 May. 2018

The first step in the alginate extraction from brown seaweed is the acidic pre-treatment. The acidic pre-treatment affected physical characteristics of brown seaweed in alkaline solution and physicochemical properties of alginate. The aim of this study to investigate the effects of pH and time of the acidic pre-treatment on the multiple response of alginate from brown seaweed *Sargassum cristaefolium* extracted using twin-screw extruder (TSE). Central composite design in Response Surface Method (RSM) was used to find the optimum condition of the acidic pre-treatment based on these responses namely residence time distribution (RTD), yield, intrinsic viscosity, alginate molecule weight. Higher RTD was observed as pH level was approximately neutral, leading to degradation of alginate polymer chain. The results demonstrated that pH and duration of the acidic pre-treatment significantly showed quadratic effects on RTD, intrinsic viscosity, and molecule weight. The optimum condition of the acid pre-treatment was found at pH of 2.90 and time of 61.74 min, resulting in RTD  $4.13 \pm 0.017$  min, yield  $35.58 \pm 0.23$  %, intrinsic viscosity  $418.77 \pm 1.74$  ml/g, and molecule weight  $198.15 \pm 2.47$  kDa.

**Keywords:** Twin-screw extruder, acid pre-treatment, alginate, *Sargassum cristaefolium*, response surface methodology

### INTRODUCTION

Alginate is a polysaccharide isolated from brown seaweed such as *Sargassum cristaefolium*. As a polymer of cell wall component, Alginate is composed of  $\beta$ -(1-4)-D-mannuronic (M) and  $\alpha$ -L-guluronic (G) subunits at different proportions and order (Torres et al. 2007; Larsen et al. 2003; Leal et al. 2008; Draget and Taylor, 2011; Fenoradosoa et al. 2010). Ratio of M/G and distribution of G and M subunits remarkably affected characteristics and functional properties of alginate (Davis et al. 2003; Jensen et al. 2012;

Lee and Mooney, 2012; Chee et al. 2011; Bertagnolli et al. 2014). It has numerous applications due to its favorable properties such as thickening, thermo-stable, emulsifying, and gelling agent (Poncelet et al. 1999; Sellimi et al. 2015; Gomez et al. 2009; Rahelivao et al. 2013), and is widely used as food supplement, delivery drug (pharmacy) control, and antitumor (Paula et al. 2007; Moebus et al. 2012; Jensen et al. 2012; Lins et al. 2013).

Alginate extraction using batch process takes time and requires a lot of reactants and solvents



(Torres et al. 2007; Fertah et al. 2014), while extraction using supercritical CO<sub>2</sub>, auto-hydrolysis, microwave, and ultrafiltration is expensive and difficult to apply in industrial scale (Balboa et al. 2013; Gonzalez-Lopez et al. 2012; Perez-Lopez et al. 2014; Quitain et al. 2013). Extraction of alginate using twin-screw extruder (TSE) is more effective and applicable for industries due to its continuous process with combination of pressure, shear stress, and temperature in the moving screw (Vauchel et al. 2008; Baron et al. 2010, Hernandez-Carmona et al. 2013).

TSE demonstrated an essential role in the transformation of physicochemical materials (Kartika et al. 2010), and was applied for chemical reactor in the extraction of natural resources such as extraction of canola oil and pretreatment of lignocellulose for bioethanol production (Dufaure et al. 1999; Evon et al. 2007; 2013; Zheng and Rehmann, 2014). TSE in the extraction of brown seaweed alginate demonstrated the advantageous properties such as continuous and rapid process, and required low volume of solvents, low waste, and safe operation (Vauchel et al. 2008; Kartika et al. 2006; 2010). Recent studies that involved TSE in the extraction of brown seaweed alginate mostly focused on investigating the effects of screw speed on RTD (Baron et al. 2010).

The acidic pre-treatment of brown seaweed is to conversion of alginate salt-including the insoluble calcium and magnesium to alginate acid and this is more easily to extract with sodium carbonate treatment (Hernandez-Carmona et al. 1999). The pH and time level acid pre-treatment affects the physical characteristics of brown seaweed in alkaline solution and physicochemical properties of alginate, and molecule alginate is hydrolyzed at low pH (Lorbeer et al. 2015; Silva et al. 2015). Therefore, a study pertaining the effects of acidic pre-treatment on RTD and physicochemical properties of alginate processed using TSE is required. This study is aimed to evaluate the effects of different pH levels and time of acidic pre-treatment on RTD and physicochemical properties of alginate from brown seaweed *Sargassum cristaefolium* extracted using twin screw extruder, and to find out optimum condition based on RTD, intrinsic viscosity, yield, and molecular weight.

## MATERIALS AND METHODS

### Materials and Reagents

*Sargassum cristaefolium* brown seaweed was obtained from Poteran Island, Sumenep, Madura, in April 2016. Fresh brown seaweed was washed using tap water and immediately transported to laboratory (within 24 h). The seaweed was washed and submerged in 0.1% KOH for 1 h, and re-washed to remove residue. The seaweed was sun dried, grounded, and sieved at 60 mesh (Subaryono, 2010). The seaweed was submerged in 0.1% formaldehyde overnight, and then washed, dried at 50°C for 6 h in cabinet dryer (Wedlock and Fasihuddin, 1990; Hernandez-Carmona et al. 1999). All chemicals including KOH, formaldehyde, hydrochloric acid (HCl) 35%, ethanol 96%, Na<sub>2</sub>CO<sub>3</sub> were technical grade, and reagent for analysis were analytical grade.

### Twin-screw extruder

The alginate extraction was performed using intermeshing co-rotating twin-screw extruder (Berto Industry BEX-DS-2256), with capacity of 7 kg/h. Three thermocouples were set to produce heat. The barrel temperature was monitored in control panel, and the high temperature was reduced by using air compressor, diameter of die was 8 mm. The extruder was operated at screw speed of 0-180 rpm, feed screw speed of 0-35 rpm. Barrel and screw profile of twin-screw extruder Berto Industry BEX-DS-2256 were exhibited in Figure 1.

### Extraction of sodium alginate

#### Pre-treatment of brown seaweed

Brown seaweed was dissolved in 0.03 M HCl according to the treatment (pH 1-5) for 30-90 min with ratio of 1:20 (b/v), depended on the treatment, and gently stirred at speed of 500 rpm. The brown seaweed was rinsed by distilled water to eliminate acid excess, and the remaining water was removed using pressure machine (Hernandez-Carmona et al. 1999).

#### Alginate extraction using twin-screw extruder

Pre-treated brown seaweed (at pH 1-5 for 30-90 min) was gradually added with Na<sub>2</sub>CO<sub>3</sub> solution (2.25%) with ratio of 1:3 (b/v), stirred and transferred into extruder hopper. Extrusion experiment for alginate extraction was operated at feed screw speed of 30 rpm, screw speed of 75 rpm, temperature of 60°C. Brown seaweed was

**Table 1. Experimental design and responses**

| No | Pre-treatment   |           |                |                | Response     |           |                            |                        |
|----|-----------------|-----------|----------------|----------------|--------------|-----------|----------------------------|------------------------|
|    | Actual variable |           | Code variable  |                | RTD (minute) | Yield (%) | Intrinsic viscosity (ml/g) | Molecular weight (kDa) |
|    | pH              | Time(min) | x <sub>1</sub> | x <sub>2</sub> |              |           |                            |                        |
| 1  | 3.00            | 60.00     | 0              | 0              | 4.05         | 34.59     | 438.27                     | 207.53                 |
| 2  | 1.00            | 30.00     | -1             | -1             | 4.35         | 31.97     | 178.72                     | 88.53                  |
| 3  | 0.17            | 60.00     | -1.414         | 0              | 4.05         | 29.85     | 159.35                     | 74.22                  |
| 4  | 5.00            | 90.00     | +1             | +1             | 4.58         | 31.45     | 139.95                     | 65.05                  |
| 5  | 3.00            | 60.00     | 0              | 0              | 4.11         | 36.16     | 426.02                     | 201.63                 |
| 6  | 5.83            | 60.00     | +1.414         | 0              | 4.55         | 28.27     | 155.12                     | 72.22                  |
| 7  | 1.00            | 90.00     | -1             | +1             | 4.00         | 29.79     | 198.72                     | 92.88                  |
| 8  | 5.00            | 30.00     | +1             | -1             | 4.35         | 29.16     | 170.29                     | 79.41                  |
| 9  | 3.00            | 17.57     | 0              | -1.414         | 4.40         | 27.35     | 150.59                     | 70.08                  |
| 10 | 3.00            | 60.00     | 0              | 0              | 4.15         | 33.68     | 436.22                     | 206.55                 |
| 11 | 3.00            | 102.43    | 0              | +1.414         | 4.05         | 32.80     | 170.60                     | 79.55                  |
| 12 | 3.00            | 60.00     | 0              | 0              | 4.13         | 35.27     | 402.28                     | 190.22                 |
| 13 | 3.00            | 60.00     | 0              | 0              | 4.10         | 34.35     | 424.49                     | 201.10                 |

moved along the rotating screws and then was released in the opening die. The extrudate was then dissolved in Na<sub>2</sub>CO<sub>3</sub> 2.25% with ratio of 1:10 (b/v), stirred. Alginate filtrate was centrifuged at 5000 rpm for 10 min to obtain supernatant. The filtrate was added with ethanol 96% with ratio of 1:2 (v/v), kept for 1 h and filtered. Alginate was washed (twice) using ethanol 70% and 96%, filtered and pressed. The alginate obtained was oven-dried at 45°C for 24 h, crushed and sieved at 60 mesh.

**RSM experimental design**

The acidic treatment was optimized using RSM central composite design consisting of two variables pH (x<sub>1</sub>) and time acid pre-treatment (x<sub>2</sub>). The design resulted in 13 combinations randomly ordered with 5 replications at center point (run 9-13) (Montgomery, 2005), as presented in Table 1. Based on experimental data, the second order was used as follow:

$$Y = \beta_0 + \sum_{i=1}^2 \beta_i x_i + \sum_{i=1}^2 \beta_{ii} x_i^2 + \sum_{i < j} \beta_{ij} x_i x_j \quad (1)$$

where Y is response; β<sub>0</sub> is intercept coefficient; β<sub>i</sub>, β<sub>ii</sub>, β<sub>ij</sub> are regression coefficients for linear, quadratic, and interaction; x<sub>i</sub>, x<sub>j</sub> are independent variables of pH and time acid pre-treatment.

The accuracy of polynomial model was analyzed using *Software Design-Expert* version 7 to obtain correlation coefficient (R) and determination coefficient (R<sup>2</sup>) of observe variables (RTD, yield, intrinsic viscosity, and molecule weight). The

significance of R and R<sup>2</sup> was statistically evaluated using F-test.

**Determination of residence time distribution**

Residence time distribution (RTD) of brown seaweed was time at which the material injected until the material released in the opening die.

**Determination of Yield**

Yield was determined as ratio of the dry weight alginate extracted to dry weight of brown alga used for extraction, then multiplied by 100%.

**Determination of intrinsic viscosity**

Alginate viscosity was assessed at 25 °C using viscometer glass with capillary diameter of 0.56 mm. To prepare alginate solution, alginate (30 mg) was dissolved in 10 ml of distilled water, stirred for 3 h at 25 °C (Chee et al. 2011). The different concentrations (0.05-0.3 g/dL) of alginate were then made. (t) was relatively measured to (t<sub>0</sub>). Intrinsic viscosity was determined by extrapolating of η<sub>sp</sub>/c concentration to zero.

Relative viscosity,

$$\eta = \frac{t}{t_0} \quad (2)$$

Specific viscosity,

$$\eta_{sp} = \eta - 1 \quad (3)$$

Reduction viscosity,

$$\frac{\eta_{sp}}{c} = \frac{\eta - 1}{c} \quad (4)$$

Intrinsic viscosity,

$$[\eta] = \lim_{c \rightarrow 0} \frac{\eta_{sp}}{c} \quad (5)$$

### Determination of molecular weight

Determination of alginate molecular weight was based on correlation of average intrinsic viscosity and molecular weight, determined by using formulation of Mark-Houwink (Eq. 6), where  $k = 0.023$  dL/g and  $a = 0.984$  proposed by Clementi et al. (1998) quoted by Fertah et al. (2014), Chee et al. (2011) and Torres et al. (2007) to empirically relate  $[\eta]$  and the weight-average molar mass ( $M_w$ ).

$$[\eta] = kM_w^a \quad (6)$$

The  $[\eta]$  is intrinsic viscosity (dL/g), and  $M_w$  is molecular weight (kDa).

## RESULTS AND DISCUSSION

### Residence time distribution

The results showed that pH and time of the acid pre-treatment significantly affected RTD. Lower pH and longer acid-treatment time resulted in lower RTD (Figure 2). This condition of lower pH may induce enhancement of Ca/H ion exchange, which more easily reacts and dissolves in sodium carbonate solution to form sodium alginate. The Ca/H ion exchange follows the first order, and its rate shows proportional correlation with pre-treatment time and acid concentration (Myklestad, 1968). The physical characteristic of brown seaweed in sodium carbonate solution at ratio of 1:3 (b/v) smoother with reduced pH level and increased duration acid pre-treatment. This phenomenon is due to the formation of porous cell wall and remove phenolic compounds because of acid pre-treatment of brown seaweed (Bertagnoli et al. 2014). This acid pre-treatment also could promote of Ca/H ions exchange, conversion of alginate salts to alginic acid was higher as acid concentration and pre-treatment time increase. The alginic acid was more extractable with sodium carbonate solution compare alginate salt (calcium and magnesium alginates) (Gomez et al. 2009; Hanh et al. 2011). Hernandez-Carmona et al. (1999) and Silva et al. (2015) reported that exchange of Ca/H ions was higher in pre-extraction in 0.1 M HCl than that pre-extraction at pH 4 or without pre-extraction treatment, alginate extractability was improve with more acid conditions.

### Yield

Treatments of pH and acid pre-treatment time remarkably influenced extractability of alginate, higher yield was obtained at lower pH and longer pre-treatment time (Figure 2). The yield was

higher at condition of pH 3 and acid pre-treatment time of 60 min, but lower at condition of pH 5 and duration acid pre-treatment in the range of 30-90 min. The widely reported that pH and duration acid treatment quadratic effect on the extractability of alginate, the extractability of alginate was increase with more acid conditions and longer duration acid treatment (Lorbeer et al. 2015). This presumably reflects conversion of insoluble alginate, calcium, magnesium to more soluble and extractable alginate using sodium carbonate. Ca/H ion exchange was relatively higher with increase in acid concentration and acid pre-treatment time. Higher acid concentration and longer acid pre-treatment effectively reduced phenolic components which could promote alkaline extraction, decreased phenolic compounds associated with alginates and inhibited alginate extraction (Gonzalez-Lopez et al. 2012; Deniaud-Bouet et al. 2014). Alginate yield using acid-treatment at pH 2 was higher than that of at pH 5 or without acid treatment (water) (Lorbeer et al. 2015; Rahelivao et al. 2013; Jayasankar, 1993). Pre-treatment which was performed at too low pH and excessive time led to degradation of alginate polymers (Gomez et al. 2009; Hernandez-Carmona et al. 1999; Silva et al. 2015).

### Intrinsic viscosity

Experimental data show that intrinsic viscosity was higher at pH 3 and acid pre-treatment time of 60 min, but lower at pH 5 and duration time of 30-90 min. The highest intrinsic viscosity (438.27 ml/g) was obtained at pH 3 and 60 min, while the lowest intrinsic viscosity (136 ml/g) was found at pH 5 and 90 min. Intrinsic viscosity obtained in this research was relatively similar to that reported by Rahelivao et al. (2013), Fenorodosa et al. (2010), Torres et al. (2009), and higher than result reported by Mahmood and Siddique (2010), Bertah et al. (2014) and Sellimi et al. (2015).

Treatment of pH and time acid pre-treatment exhibited quadratic effect on intrinsic viscosity of alginate extracted by twin-screw extruder (Figure 2). Intrinsic viscosity was positively correlated at pre-treatment condition of pH 3 and 60 min, decreased at acid pre-treatment condition of pH 1 and 5 for the range of 30-90 min. This is because the degradation of the polymer chain is getting worse at the pre-treatment of pH 1 and 5. Degradation of alginate molecules resulted from reaction of  $\beta$ -elimination in 4-O-glycosidic bonds,

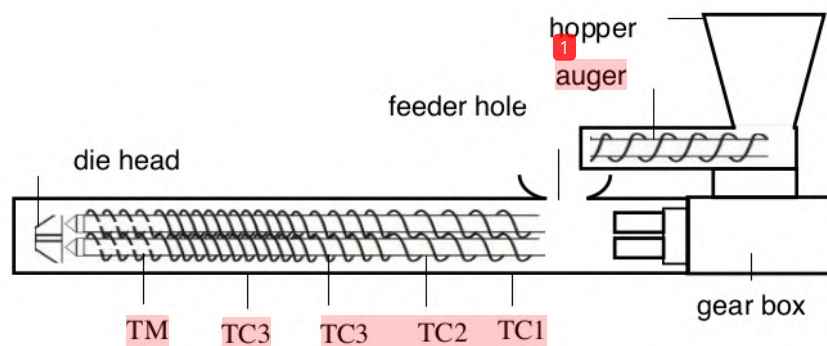


**Table 2. The quality of fit of the second-order models.**

| Function                    | Model significance (Ps) | Lack of fit (PL) | Corelation coefficient (R <sup>2</sup> ) | Coefficient of variance (C.V) |
|-----------------------------|-------------------------|------------------|--|-------------------------------|
| Residence time distribution | 0.0005                  | 0.0558           | 0.9335                                   | 1.60                          |
| Yield                       | 0.0059                  | 0.1271           | 0.8656                                   | 4.28                          |
| Intrinsic viscosity         | < 0.0001                | 0.3367           | 0.9854                                   | 6.22                          |
| Molecular weight            | < 0.0001                | 0.3367           | 0.9915                                   | 6.22                          |
| Intrinsic viscosity         | < 0.0001                | 0.3367           | 0.9854                                   | 6.22                          |

**Table 3. Components and optimized response, goal, limits, and importance in the optimization stages of the formula**

| Response component                  | Target   | Lower limit | Upper limit | importance |
|-------------------------------------|----------|-------------|-------------|------------|
| pH                                  | In range | 1           | 5           | 3(+++)     |
| Waktu (menit)                       | In range | 30          | 90          | 3(+++)     |
| Residence time distribution (menit) | In range | 4           | 4.58        | 3(+++)     |
| Yield (%)                           | Maximum  | 27.35       | 36.18       | 5(++++)    |
| Intrinsic viscosity (ml/g)          | Maximum  | 139.95      | 438.27      | 5(++++)    |
| Molecular weight (kDa)              | maximum  | 65.05       | 207.53      | 5(++++)    |



**Figure 1. Schematic modular barrel and screw profile of corotative twin screw extruder Berto Industry EX-DS-2256 (serial number: BC-0405-054-08-004). TC= groove transfer direct pitch element (TC1=300 mm, TC2=220 mm, TC3=140 mm, TC4= 120 mm), TM= groove mixing pitch element (80 mm), Total long element=800 mm**

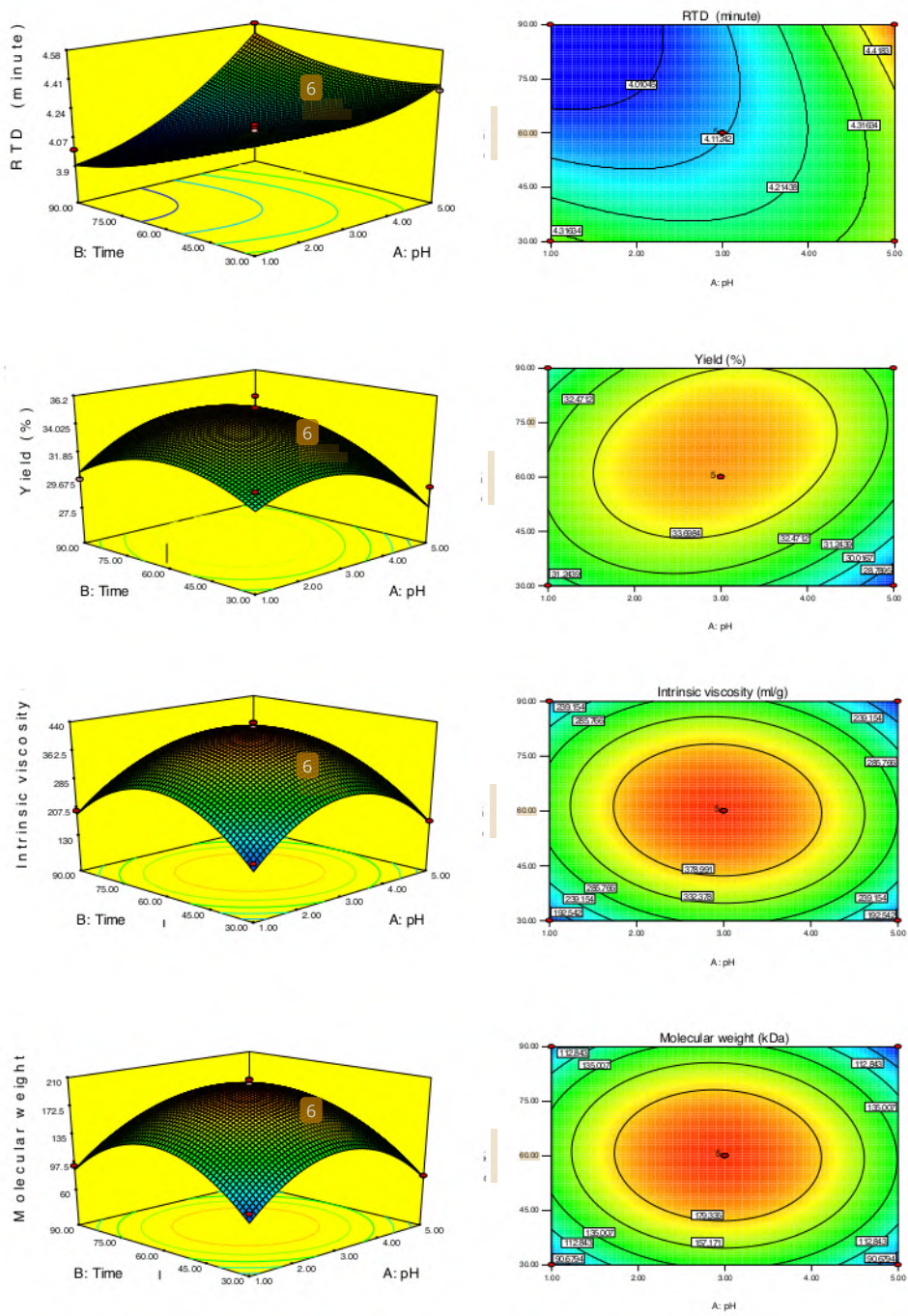


Figure 2. Response surface (left) and contour plot (right) of experimental responses as a result of different pH levels and acid pre-treatment time

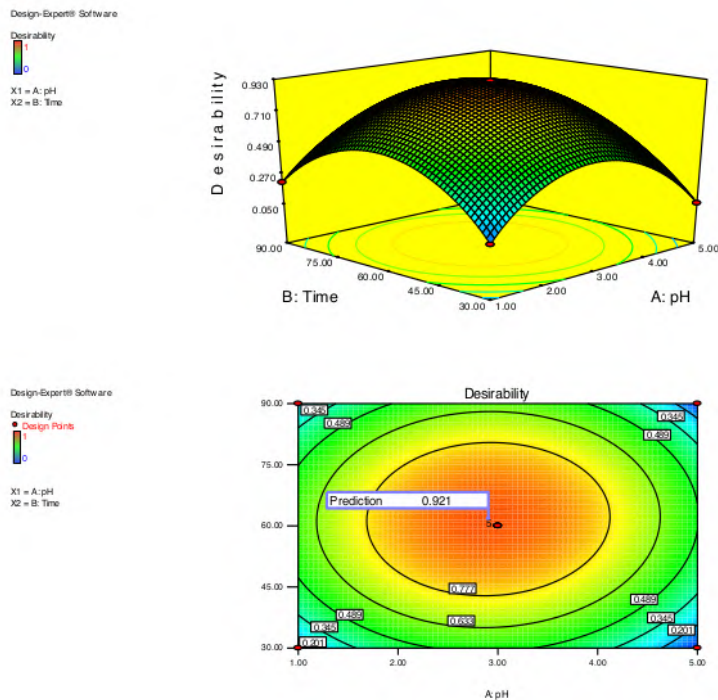


Figure 3. Desirability value of optimum condition predicted by Design Expert version 7

which formed deoxyhexopyranuronic, and hydrolytic reaction was catalyzed by proton from glycuronan chain, as well as auto-oxidation of reduction components (Smidsrod et al. 1969; Haug et al. 1967). Hernandez-Carmona et al. (1999) found that acidity level in pre-treatment stage negatively correlated with alginate viscosity, the viscosity rapidly decreased in acid treatment at 0.1 M HCl. The acid pre-treatment at around neutral condition ineffective reduction of phenol, low Ca/H ion exchange, higher residence time distribution, and stronger specific mechanical energy effect, leading to breakdown of alginate polymer main chains (Wedlock and Fasihuddin, 1990; Kartika et al. 2010; Baron et al. 2010). Alginate viscosity with acid pre-treatment was higher than that of without acid pre-treatment (Jayasankar, 1993).

#### Alginate molecular weight

Experimental data demonstrated that the highest molecular weight was obtained at pH 3 and 60 min, while the lowest one was found at pH 5 and 90 min. Statistical analysis showed that acid pre-treatment at pH 1-5 and 30-90 min significantly affected molecular weight of alginate ( $P < 0.05$ ). Alginate molecular weight was positively increased until pH 3 and duration of 60 min, and decreased at pH 1 and 5 (Figure 2). This is associated with degradation of alginate polymer chains induced by  $\beta$ -elimination (4) acid pre-treatment stage at low pH level (Gomez et al. 2009; Hernandez-Carmona et al. 1999). In addition, it also might be affected by auto-oxidation of phenolic compounds, which possibly promoted formation of peroxide hydrogen in acid pre-treatment near neutral pH level. Reducing components by peroxide hydrogen yielded radical hydroxyl that could break alginate molecules



(Smidsrod et al. 1963; Haug et al. 1963). Reduced phenolic compound in acid treatment at about neutral pH was not effective, and its presence drastically degraded alginate chain during alkaline extraction (Wedlock and Fasihuddin, 1990). Lorbeer et al. (2015) report that alginate molecule weight relative high an acid pre-treatment at pH 3.5 compared to pH 5. At pH 5, exchange of Ca/H was relatively low and residence time distribution was higher thus increasing specific mechanical energy effect, which led to degradation of alginate polymer chains (Hernandez-Carmona et al. 1999; Kartika et al. 2010; Baron et al. 2010).

#### Prediction model and statistical analysis

RSM was used to optimize effects of acid pre-treatments on alginate extracted by twin-screw extruder. The various pH levels (1, 3, 5) and pre-treatment time (30, 60, 90 min) are variables for central composite design (CCD). The second-order polynomial models RTD, yield, intrinsic viscosity, and molecule weight (code variables) are presented below:

$$y = +4,11 + 0,16 x_1 - 0,077x_2 + 0,11x_1^2 - 0,073x_2^2 + 0,15x_1x_2 \quad R^2=0,9335$$

$$y = +34,81 - 0,42x_1 + 0,98x_2 - 2,62x_1^2 - 2,11x_2^2 + 1,12x_1x_2 \quad R^2=0,8617$$

$$y = +425,46 - 9,15x_1 + 2,24x_2 - 130,86 x_1 - 129,18 x_2^2 - 12,58x_1x_2 \quad R^2=0,9914$$

$$y = +310,89 - 6,70x_1 + 1,65x_2 - 97,35 x_1^2 - 96,12x_2^2 - 9,21x_1x_2 \quad R^2=0,9915$$

Polynomial models of second order are evaluated according to significance, lack of fit, correlation coefficient ( $R^2$ ) and coefficient of variance (C.V.), as observed in Table 2. The proper prediction models have significance  $P < 0.05$ ,  $R^2 \geq 0.8$ , lack of fit  $> 1$ , coefficient of variance (C.V.)  $\leq 10\%$  (Montgomery, 2005). Based on these parameters, second order polynomial models meet the criteria, thus they are acceptable for predicting optimal response.

#### Multiple-response optimization and verification

After the mathematical models are determined, optimization is carried out to obtain the best desirability, considering target and importance of responses (Table 3). The optimum condition for extraction of brown seaweed alginate was obtained at pH 2.90 and acid treatment time of 61.74 min. At this condition, the prediction of response value was RTD 4.096 min, yield 34.87 %, intrinsic viscosity 425.327 ml/g, molecular weight 201.333 kDa, which resulted in desirability value of 0.921 (Figure 3). Desirability value most

equal to 1 indicated that optimum point predicted by Design Expert had high validity (Ale et al. 2012).

The prediction of optimum condition (pH 2.90 and time 61.74 min) was the verified using 3-replicated experiments, which resulting in RTD  $4.13 \pm 0.017$  min, yield  $35.58 \pm 0.23$  %, intrinsic viscosity  $418.77 \pm 1.74$  ml/g, and molecule weight  $198.15 \pm 2.47$  kDa. The verification demonstrated 95% PI low and 95% PI high, indicating that the verification results in attaining maximum yield, intrinsic viscosity, and molecular weight were consistent and valid (Qiao et al. 2009; Sugiono et al. 2014). The optimum condition of the acid pre-treatment of brown seaweed in this research agreement with the findings of Rahelivao et al. (2013), but slightly lower than the pH of 3.2 suggested by Lorbeer et al. (2015) and the pH of 4 suggested by Gomez et al. (2009). Multiple-response alginate at the optimal condition was higher than result reported by Vauchel et al. (2008).

#### CONCLUSION

Different pH levels and acid pre-treatment time significantly altered residence time and quality of brown seaweed *Sargassum cristaefolium* alginate extracted using twin-screw extruder. The optimum acid pre-treatment condition was achieved at pH 2.90 and time 61.80 min, resulting in RTD  $4.13 \pm 0.017$  min, yield  $35.58 \pm 0.23$  %, intrinsic viscosity  $418.77 \pm 1.74$  ml/g, and molecular weight  $198.15 \pm 2.47$  kDa.

#### CONFLICT OF INTEREST

The authors declared that present study was performed in absence of any conflict of interest".

#### ACKNOWLEDGEMENT

Authors would like to thank Technopark, Bogor Agricultural University, for facilitating utilization of twin-screw extruder.

#### AUTHOR CONTRIBUTIONS

This manuscript is part of the PhD Dissertation (Agricultural Product Technology) of first author advised by all co-author. Sugiono was responsible for conception, design, analysis and interpretation of data, drafting and revising and give final approval of the version to be submitted. Masruri, Teti Estiasih and Simon Bambang Widjanarko were responsible for supervise for conception, design, analysis and interpretation of data, and processing of the manuscript.



Copyrights: © 2017 @ author (s).

This is an open access article distributed under the terms of the [Creative Commons Attribution License \(CC BY 4.0\)](https://creativecommons.org/licenses/by/4.0/), which permits unrestricted use, distribution, and reproduction in any medium, provided the original author(s) and source are credited and that the original publication in this journal is cited, in accordance with accepted academic practice. No use, distribution or reproduction is permitted which does not comply with these terms.

## REFERENCES

- Ale MT, Mikkelsen JD, Meyer AS, 2012. Designed optimization of a single-step extraction of fucose-containing sulfated polysaccharides from *Sargassum sp.* *Journal of Applied Phycology*, 24:715-723.
- Balboa EM, Rivas S, Moure A, Dominguez H, Parajo JC, 2013. Simultaneous extraction and depolymerization of fucoidan from *Sargassum muticum* in aqueous media. *Marine Drugs*.11(11):4612-4627.
- Baron R, Vauchel P, Kaas R, Arhaliass A, Legrand J, 2010. Dynamical modeling of a reactive extrusion process: focus on residence time distribution in a fully intermeshing co-rotating twin-screw extruder and application to an alginate extraction process. *Chemical Engineering Science*, 65:3313-3321.
- Bertagnolli C, Paula A, Espindola D, Klienubing SJ, Tasic L, Silva MGCD, 2014. *Sargassum felipendulla* alginate from Brazil: Seasonal influence and characteristics. *Carbohydrate Polymers*, 111:619-623.
- Chee S, Wong P, Wong C, 2011. Extraction and characterisation of alginate from brown seaweeds (Fucales, Phaeophyceae) collected from Port Dickson, Peninsular Malaysia. *Journal of Applied Phycology*, 23:191-196.
- Clementi F, Mancini M, Moresi M, 1998. Rheology of alginate from *Azotobacter vinelandii* in aqueous dispersions. *Journal of Food Engineering*, 36:51-62.
- Davis TA, Lanes F, Volesky B, Diaz-Pulido G, McCook L, Mucci A, 2003. <sup>1</sup>H-NMR study of Na alginates extracted from *Sargassum spp.* in relation to metal biosorption. *Applied Biochemistry and Biotechnology*, 110:75-89.
- Deniaud-Bouet E, Kervarec N, Michel G, Tonon T, Kloareg B, Hervé C, 2014. Chemical and enzymatic fractionation of cell walls from Fucales: insights into the structure of the extracellular matrix of brown algae. *Annals of Botany*, 114:1203-1216
- Dragnet K, Taylor C, 2011. Chemical, physical and biological properties of alginates and their biomedical implications. *Food Hydrocolloids*, 25(2):251-56.
- Dufaure C, Leyris J, Rigal L, Mouloungui Z, 1999. A Twin-Screw Extruder for Oil Extraction : I. Direct Expression of Oleic Sunflower Seeds. *Journal American Oil Chemists' Society*, 76(9):1073-1010.
- Evon P, Kartika IA, Cerny M, Rigal L, 2013. Extraction of oil from jatropha seeds using a twin-screw extruder: Feasibility study. *Industrial Crops and Products*, 47:33-42.
- Evon P, Vandenbossche V, Pontalier P, Rigal L, 2007. Direct extraction of oil from sunflower seeds by twin-screw extruder according to an aqueous extraction process: Feasibility study and influence of operating conditions. *Industrial Crops and Products*, 26:351-359.
- Fenoradosoa TA, Ali G, Delattre C, Laroche C, Petit E, Wadouachi A, Michaud P, 2010. Extraction and characterization of an alginate from the brown seaweed *Sargassum turbinarioides* Grunow. *Journal of Applied Phycology*, 22:131-137.
- Fertah M, Belfkira A, Dahmane EM, Taurite M, Brouillette A, Taurite M, 2014. Extraction and characterization of sodium alginate from Moroccan *Laminaria digitata* brown seaweed. *Arabian Journal of Chemistry*, 5(3):1878-1888.
- Gomez CG, Lambrecht MVP, Lozano JE, Rinaudo M, Villar MA, 2009. Influence of the extraction-purification condition on final properties of alginates obtained from brown algae (*Macrocystis pyrifera*). *International Journal of Biological Macromolecules*, 44:365-371
- Gonzalez-Lopez A, Moure A, Dominguez H, 2012. Hydrothermal fractionation of *Sargassum muticum* biomass. *Journal of Applied Phycology*, 24:1569-1578.
- Hahn T, Lang S, Ulber R, Muffler K, 2012 Novel procedures for the extraction of fucoidan from brown algae. *Process Biochemistry*, 47(12): 1691-1698.
- Haug A, Larsen B, Smidsrod O, 1963. The degradation of alginates at different pH values. *Acta Chemica Scandinavica*, 17:1466-1468
- Haug A, Larsen B, Smidsrod O, 1967. Alkaline degradation of alginates. *Acta Chemica*

- Scandinavica, 21:2859-2870
- Hernandez-Carmona G, McHugh D.J., Arvizu-Higuera D.L., Rodriguez-Montesinos, 1999. Pilot plant scale extraction of alginate from *Macrocystis pyrifera*. 1. Effect of pre-extraction treatments on yield and quality of alginate. *Journal of Applied Phycology*, 10:507-513.
- Hernandez-Carmona G, Freile-Pelegrin Y, Hernandez-Garebay E, 2013. Conventional and alternative technologies for the extraction of algal polysaccharides. Woodhead publishing limited, pp. 475-516
- Jayasankar R, 1993. On the yield and quality of sodium alginate from *Sargassum wightii* (greville) by pre-treatment with chemicals. *Seaweed Research and Utilisation*, 16(1&2): 63-66.
- Jensen M.G., Knudsen J.C., Viereckb N, Kristensen M, Astrup A, 2012. Functionality of alginate based supplements for application in human appetite regulation. *Food Chemistry*, 132:823–829.
- Kartika I.A., Pontalier P.Y., Rigal L. Extraction of oleic sunflower oil by twin-screw extruder: screw configuration and operating conditions effects. In. Proc. 16<sup>th</sup> International Sunflower Conference. Processing, Technology and New Uses. Fargo. ND USA; 2006.
- Kartika I.A., Pontalier P.Y., Rigal L, 2010. Twin-screw extruder for oil processing of sunflower seeds: Thermo-mechanical pressing and solvent extraction in a single step. *Industrial Crops and Products*, 32(3):297–304.
- Larsen B, Salem DMSA, Sallam MAE, Mishrikey MM, Beltagy AI, 2003. Characterization of the alginates from algae harvested at the Egyptian Red Sea coast. *Carbohydrate Research*, 338:235-336.
- Leal D, Matsuhiro B, Rossi M, Carusso F, 2008. FT-IR spectra of alginic acid block fractions in three species of brown seaweeds. *Carbohydrate Research*, 343:308-316.
- Lee KY, Mooney DJ, 2012. Alginate: properties and biomedical applications. *Progress in Polymers Science*, 37:106-126.
- Lins KOAL, Vale ML, Ribeiro RA, Costa-Lotufo LV, 2013. Proinflammatory activity of an alginate isolated from *Sargassum vulgare*. *Carbohydrate Polymers*, 92(1): 414–420.
- Lorbeer AJJ, Lahnstein, Bulone V, Nguyen T, Zhang W, 2015. Multiple-response optimization of the acidic treatment of the brown alga *Ecklonia radiata* for the sequential extraction of fucoidan and alginate. *Bioresource Technology*, 197:302-309
- Mahmood SJ, Siddique A. 2014. Ionic studies of sodium alginate isolated from *Sargassum terrarium* (brown algae) karachi coast with 2,1-electrolyte. *Journal of Saudi Chemical Society*, 14: 117-123
- Moebus K, Siepmann J, Bodmeier R. 2012. Novel preparation techniques for alginate–poloxamer microparticles controlling protein release on mucosal surfaces. *European Journal of Pharmaceutical Sciences*, 45:358–366.
- Montgomery DC, 2005. Response surface methods and designs. New York. USA: John Willy and Sons. Inc
- Myklestad S, 1968. Ion-exchange properties of brown algae. Determination of rate mechanism for calcium hydrogen ion exchange for particles from *Laminaria hyperborea* and *Laminaria digitata*. *Journal of Applied Chemistry*, 18:30–36.
- Paula A, Sousa AD, Rocha M, Pessoa C, Odorico M, Moraes D, Dário F, Filho R, Paula A, Nunes N, Costa-lotufo LV, 2007. In vivo growth-inhibition of Sarcoma 180 tumor by alginates from brown seaweed *Sargassum vulgare*. *Carbohydrate Polymers*, 69:7–13.
- Perez-Lopez P, Balboa EM, Gonzalez-Garcia S, Dominguez H, Feijoo G, Moreira T, 2014. Comparative environmental assessment of valorization strategies of the invasive macroalga *Sargassum muticum*. *Bioresource Technology*, 161:137–148.
- Poncelet D, Babak V, Dulieu C, Picot A, 1999. A physico-chemical approach to production of alginate beads by emulsification-internal ionotropic gelation. *Colloids and Surfaces A: Physicochemical and Engineering Aspects*, 155: 171–176
- Qiao D, Hu B, Gan D, Sun Y, Ye, Zeng X, 2009. Extraction optimized by using response surface methodology, purification and preliminary characterization of polysaccharide from *Hyriopsis cumingi*. *Carbohydrate Polymers*, 76:422-429.
- Quitain AT, Kai T, Sasaki M, Goto M, 2013. Microwave–hydrothermal extraction and degradation of fucoidan from supercritical carbon dioxide deoiled *Undaria pinnatifida*. *Industrial & Engineering Chemistry Research*, 52(23):7940-7946.
- Rahelivao, Pascaline M, Andriamanantoanina H, Heyraud A, Rinaudo M, 2013. Structure and properties of three alginates from



- madagascar seacoast algae. Food Hydrocolloids, 32(1):143–46.
- Sellimi S, Younes I, Ayed HB, Maalej H, Montero V, Rinaudo M, Dahia M, Mechichi T, Hajji M, Nasri M, 2015. Structural, physicochemical and antioxidant properties of sodium alginate isolated from a Tunisian brown seaweed. International Journal of Biological Macromolecules, 72: 358–1367.
- Silva M, Gomes F, Oliveira F, Morais S, Delerue-Matos C, 2015. Microwave-assisted alginate extraction from Portuguese saccorhiza polyschides– influence of acid pretreatment. World Academy of Science, Engineering and Technology. International Journal of Chemical, Nuclear. Materials and Metallurgical Engineering, 9(1): 30-33.
- Smidsrod O, Haug A, Larsen B, 1963. Degradation of alginate in the presence of reducing compounds. Acta Chemica Scandinavica, 17:2628-2637.
- Smidsrod O, Larsen B, Painter T, Haug A, 1969. The role of intramolecular autocatalysis in the acid hydrolysis of polysaccharides containing 1.4-linked hexuronic acid. Acta Chemica Scandinavica, 23:1573-1580.
- Subaryono, Apriani SNK, 2010. Effect of decantation filtrate on alginate extraction process from *Sargassum sp.* of the quality produced. Journals Post-harvest and Marine Technology and Fisheries, 5(2):165-175.
- Sugiono, Widjanarko SB, Soehono LA, 2014. Extraction optimization by response surface methodology and characterization of fucoidan from brown seaweed *Sargassum polycystum*. International Journal of ChemTech Research, 6(1):195-205.
- Torres MR, Saosa APA, Filho EATS, Melo DF, Feitosa JPA, Paula RCMD, Lima MGS, 2007. Extraction and physicochemical characterization of *Sargassum vulgare* alginate from Brazil. Carbohydrate Research, 342:2067-2074.
- Vauchel P, Kaas R, Arhaliass A, Baron R, Legrand J, 2008. A new process for extracting alginates from *Laminaria digitata*: reactive extrusion. Food and Bioprocess Technology, 1(3):297-300.
- Wedlock DJ, Fasihuddin BA, 1990. Effect of formaldehyde pre-treatment on the intrinsic viscosity of alginate from various brown seaweeds. Food Hydrocolloids, 4(1): 41-47.
- Zheng J, Rehmann L, 2014. Extrusion Pretreatment of Lignocellulosic Biomass: A Review. International Journal of Molecular Sciences, 15:18967-18984

# Multiple-response optimization of the acidic pretreatment of the brown alga *Sargassum cristaefolium*

## ORIGINALITY REPORT

11%

SIMILARITY INDEX

11%

INTERNET SOURCES

8%

PUBLICATIONS

5%

STUDENT PAPERS

## PRIMARY SOURCES

|   |  |    |
|---|--|----|
| 1 | <a href="http://uim.ac.id">uim.ac.id</a><br>Internet Source  | 2% |
| 2 | Submitted to King Abdulaziz University<br>Student Paper  | 2% |
| 3 | <a href="http://dokumen.pub">dokumen.pub</a><br>Internet Source  | 1% |
| 4 | Lorbeer, Andrew John, Jelle Lahnstein, Vincent Bulone, Trung Nguyen, and Wei Zhang.<br>"Multiple-response optimization of the acidic treatment of the brown alga <i>Ecklonia radiata</i> for the sequential extraction of fucoidan and alginate", Bioresource Technology, 2015.<br>Publication | 1% |
| 5 | Submitted to Universitas Diponegoro<br>Student Paper   | 1% |
| 6 | <a href="http://dspace.nbuu.gov.ua">dspace.nbuu.gov.ua</a><br>Internet Source  | 1% |
| 7 | <a href="http://mafiadoc.com">mafiadoc.com</a><br>Internet Source  | 1% |



8

proceeding.uim.ac.id

Internet Source

1 %

9

www.tandfonline.com

Internet Source

1 %

10

rjoas.com

Internet Source

1 %

11

westminsterresearch.westminster.ac.uk

Internet Source

1 %

Exclude quotes On

Exclude matches < 1%

Exclude bibliography On