UNIVERSITI PUTRA MALAYSIA

INDOOR AND OUTDOOR CULTURE OF SPIRULINA (Arthrospira platensis) GROWN IN DIFFERENT SALINITY IN SULTANATE OF OMAN

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FS 2017 29

INDOOR AND OUTDOOR CULTURE OF SPIRULINA (*Arthrospira platensis*) GROWN IN DIFFERENT SALINITY IN SULTANATE OF OMAN

By

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Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfillment of the Requirements for the Degree of Master of Science

April 2017

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfillment of the requirement for the degree of Master of Science

INDOOR AND OUTDOOR CULTURE OF SPIRULINA (*Arthrospira platensis*) GROWN IN DIFFERENT SALINITY IN SULTANATE OF OMAN

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Chairman : Professor Ahmad Ismail, PhD
Faculty : Science

Oman is in semi-arid and arid region, which receive extremely high light intensity and limited rainfall annually. Dry weather condition has caused diminishing underground water resources and has lead to seawater intrusion problems. This study is to explore the potential of Spirulina (*Arthrospira platensis*) that can be used to be cultured as a solution to the seawater intrusion. Most crops depend on freshwater or underground water resources, however Spirulina has the ability to grow and adapt to high saline condition. The experiment was conducted in the Agricultural Experimental Station of Sultan Qaboos University, Muscat, Oman. Result of the study concluded that with sufficient acclimatization, Spirulina can be grown in salinity ranges from 10 to 40 psu without having large differences of dry weight biomass, biochemical composition and fatty acid profile. In this study, Spirulina cells have produced the highest dry weight (g L-1) to 10 psu in ten days of average at 0.506 ± 0.039. Carbohydrates are the highest (27.29 ± 0.518) and high protein (%) also can be produced by Spirulina cultured with 10 psu in the external environment (outdoor), in which lipid and ash content (%) is low were produced. However, the amount of SAFA, MUFA and PUFA (% dry weight) obtained with 10 psu did not differ significantly (p <0.05) than other salinity concentration. The market price for Spirulina is extremely high compare to the fruits and vegetables, farmers in Oman will consider these types of cultivation as the best solution for them farming salinity problems whatever the percentage of the salinity was in their farm. At the same time, the government may take this opportunity to move part of the recruitment pressure for those who lost their farm because of the salinity intrusion by providing better solution. Spirulina farming will create so many good benefits to the country.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Sarjana Sains

KULTUR SPIRULINA (*Arthrospira platensis*) DI KAWASAN DALAM DAN DI LUAR DITUMBUHKAN DALAM PELBAGAI TAHAP KEMASINAN DI OMAN

Oleh

ALMAHROUQI HAFIDH ALI SAIF

April 2017

Pengerusi : Profesor Ahmad Ismail, PhD
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Oman adalah sebuah negara yang berada dalam kawasan yang separuh gersang dan kering sepenuhnya, yang menerima keamatan cahaya yang sangat tinggi dan hujan yang terhad setiap tahun. Keadaan cuaca kering telah menyebabkan kekurangan sumber air bawah tanah dan telah membawa kepada masalah kemasukan air laut. Kajian ini bertujuan untuk meneroka potensi Spirulina (*Arthrospira platensis*) yang boleh digunakan untuk sektor pertanian sebagai satu penyelesaian kepada pencerobohan air laut yang berterusan. Kebanyakan tanaman bergantung kepada air tawar atau sumber air bawah tanah, bagaimanapun Spirulina mempunyai keupayaan untuk berkembang dan menyesuaikan diri dengan keadaan kemasinan air yang tinggi. Eksperimen telah dijalankan di Stesen Uji kaji Pertanian Universiti Sultan Qaboos, Muscat, Oman. Berdasarkan hasil kajian yang telah dijalankan, kesimpulan yang dapat dirumuskan bahawa dengan penyesuaian yang mencukupi, Spirulina boleh ditanam di dalam tahap kemasinan 10-40 psu tanpa memperolehi perbezaan yang ketara dari segi biomas berat kering, komposisi biokimia dan profil asid lemak. Dalam kajian ini, sel-sel Spirulina telah menghasilkan berat kering tertinggi (g L^{-1}) dengan 10 psu dalam purata untuk sepuluh hari pada 0,506 ± 0.039. Karbohidrat tertinggi (27.29 ± 0,518) dan protein tinggi (%) juga telah dapat dihasilkan dengan Spirulina yang diternak dengan 10 psu dalam keadaan persekitaran luar, di mana lipid dan kandungan abu (%) yang rendah telah dihasilkan. Namun begitu, jumlah SAFA, MUFA dan PUFA (% berat kering) yang diperolehi dengan 10 psu tidak berbeza dengan ketara (p <0.05) dari kepekatan kemasinan yang lain. Harga pasaran untuk Spirulina adalah amat tinggi berbanding dengan buah-buahan dan sayur-sayuran, petani di Oman akan mempertimbangkan jenis penanaman sebagai penyelesaian yang terbaik untuk sektor pertanian mereka dalam menangani masalah kemasinan itu di ladang mereka. Pada masa yang sama, kerajaan boleh mengambil

kesempatan ini untuk menggerakkan bahagian pengurusan bagi mereka yang kehilangan ladang mereka kerana kemasukan air laut yang berterusan dan pencerobohan kemasinan dengan menyediakan penyelesaian yang lebih baik. Pertanian pengkulturan Spirulina akan mewujudkan banyak faedah yang baik kepada negara.

ACKNOWLEDGEMENTS

I would like to express my gratitude to my supervisors Professor Ahmad Ismail and Dr Hishamuddin Omar for the useful comments, remarks and engagement through the learning process of this master thesis. The door to office was always open whenever I ran into a trouble spot or I had a question about my work or writing. They consistently allowed this paper to be my own work, but steered me in the right the direction whenever they thought I needed it.

I would like to thank College of Agricultural and Marine Sciences, Sultan Qaboos University for the great support.

I would also like to thank my colleague who has encouraged and helped me in this research project: - Dr. Mohamed Amar Naqqiuddin, Mr. Jamal Al-Sabahi and Mrs. Huda khlafan Al-Ruqaishi.

Finally, I must express my very profound gratitude to my family for providing me with unfailing support and continuous encouragement throughout my years of study. This accomplishment would not have been possible without them. Thank you.

I certify that a Thesis Examination Committee has met on 18 April 2017 to conduct the final examination of Almahrouqi Hafidh Ali Saif on his thesis entitled "Indoor and Outdoor Culture of Spirulina (*Arthrospira platensis*) Grown in Different Salinity in the Sultanate of Oman" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Master of Science.

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LIST OF ABBREVIATIONS

%	Percentage
°C	Degree
µg	Microgram
µg/day	Microgram per day
µg/g	Microgram per gram
µg day^{-1}	Microgram per day
µg g^{-1}	Microgram per gram
µl	Microlitre
µm	Micrometre
µmol L^{-1}	Micromolar per litre
µmol s^{-1} m^{-2}	Micromolar per second metre square
ANOVA	Analysis of variance
$CHCl_3$	Chloroform
cm	Centimetre
CO_2	Carbon dioxide
DW	Dry weight
L	Litre
Ly	Solar radiation
mg/100 g	Milligram per hundred gram
mg L^{-1}	Milligram per litre
ml	Millilitre
mm	Milimetre
Na_2CO_3	Sodium carbonate
nm	Nanometre

psu	Practical salinity unit
rpm	Round per minute
SD	Standard deviation
SE	Standard error
Se	Selenium
SPSS	Statistical Package for Science Social
UV	Ultraviolet
v/v	volume/volume

CHAPTER 1

INTRODUCTION

1.1 Introduction

The Sultanate of Oman is located in the south eastern quarter of the Arabian Peninsula and the latitude and longitude for the country are 22.7465° N, 57.1203° E. It has a total area of 309,501 km^2. It has a coastline of almost 3,165 km. Oman have arid and semi-arid climate conditions with higher humidity in coastal areas. Average annual rainfall varies from 20mm/yr in the interior to 300mm/yr along the coast (FAO, 2009). The total population in 2013 was 3.855 million, 2.172 Omanis and 1.683 foreigners (NCSI, 2013b). Oman experience severe drought and limited rainfall which caused serious problem to fulfill the water requirement for agricultural and domestic consumption.

Since Oman is in semi-arid and arid country, water for agriculture relies exclusively from ground water. Being in region with little rainfall and low humidity, most of the water for agriculture is loss through evapotranspiration, aggressive withdrawal from the aquifer and water loses by conventional irrigation system. After 1980's when the government introduced mechanized water pumping and transport system, the agriculture activities have increased tremendously followed with the over withdrawal of water resources from the aquifer especially Batinah region where more than 53% of the Oman agriculture production takes place. Agricultural practice is very important for food security but currently this country is still facing crisis such as seawater intrusion causing many abandon farmlands. Huge lost of crops are disastrous due to increasing infertile agriculture land.

Limited rain to replenish underground water resources and indiscriminate withdrawal of underground water resources have caused underground water depletion leading to seawater intrusion (Zekri *et al*., 2010). Presently, the salinity at Batinah coastline farm can reach to 35 ‰ but lower as it get further away from the sea side. However, as more underground water is extracted, the seawater intrusion is moving farther toward inland making more farms decimated from high saline water. Present solution to recharge underground water such as construction of dam for irrigation is very costly and will take some time. Modern agriculture practice to reduce water loses due to evapotranspiration is still not enough to deal with salt water intrusion. Dam construction is one of the solutions to increase the underground water recharge which to some extent help in solving the seawater intrusion.

Another effort to reduce water consumption is through recycling wastewater for agriculture use. Genetic manipulation for high saline tolerant crop will take a while for large scale farming. The best alternative would be by cultivating microalgae which can be grown in saline conditions. Algae are known to adapt well to the saline medium. Culture of marine microalgae has been initiated but still on research level and it will take a while to reach commercialization level. However many studies carried out elsewhere have shown that blue green microalgae such as Spirulina can be cultured in sea water up to 40 part per thousand and can also be grown in waste water directly or treated waste water. In case of culturing Spirulina in wastewater directly, the product is only fit for animal feed.

Spirulina (*Arthrospira platensis*) can grow and adapt to different salinity up to 35 psu (Ravelonandro *et al*., 2011). It has multiple benefits: higher productivity compared to terrestrial plant, can be grown land or water based system, produces oxygen, used up CO_2, get higher net profit than traditional crop and the crop can be harvested much faster. The nutritional value of Spirulina with its high production rate makes it commercially attractive. It has high protein content up to 68% (Phang *et al*., 2000), essential fatty acids like γ-linolenic acid, minerals, photosynthetic pigments (cyanophycean), unsaturated fatty acids and lipids, β-carotene, B-group vitamin, vitamin E, iron potassium and chlorophyll (Habib *et al.,* 2008).

Spirulina cultivation is an excellent idea for the arid area especially with low water availability for the terrestrial crop and most of the land is desert which is not suitable for vegetation. Israel is developing Spirulina culture and has a very good technology to grow it in mass cultivation (Cohen and Vonshak, 1991; Vonshak, 1987; Vonshak *et al*., 1996; Vonshak *et al.,* 1988; Vonshak, 1990; Vonshak *et al.,* 1983; Vonshak and Richmond, 1981).

Culturing Spirulina offer better advantages that other efforts mentioned previously because it is several times more productive than terrestrial crops in term of biomass and require low usage of lands for microalgae cultivation, high protein content, beneficial fatty acid, rich in vitamins, high mineral content and most important it uses less water than terrestrial crop.

Since Oman is lacking in arable land, culturing microalgae would be a better proposition. However presently in Oman, there is no serious study to cultivate Spirulina. There was one project initiated to solve the issue of brine water from desalination plants with cultivation of algae (Mohamed *et al.,* 2005). This will be the second trial in Oman. To solve irrigation water crisis in Oman, many companies was established to construct and operate a world class wastewater collection and treatment system in Muscat. With increasing source of wastewater and abundant degraded land for agriculture, the government has looked into many potential projects for better future of Oman. The idea of cultivation microalgae replacing old agricultural activities may be a positive solution which could offer the people of Oman more interesting jobs such as modern farmer and also for other purposes of food, pharmaceuticals, biomass, biodiesel, energy and more.

1.2 Objectives

1.2.1 General objective

This research will focus on finding the solution for the seawater intrusion in Oman using Spirulina (*Arthrospira platensis*).

1.2.2 Specific objectives

The objectives of this research are:

1. To explore the productivity of *A. platensis* in different salinity (10, 20, 30 and 40 psu) under Oman weather conditions.
2. To determine the proximate composition of *A. platensis* under different salinity.
3. To access the fatty acids profiling of *A. platensis* under different salinity.

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