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Heavy Metal Levels in Saudi Arabian *Spirulina*

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Abstract: A small farm of the microalga *Spirulina platensis* (Nordstedt) Geitler was established in Saudi Arabia in 1999. The levels of arsenic (As), cadmium (Cd), copper (Cu), iron (Fe), mercury (Hg), manganese (Mn), lead (Pb) and zinc (Zn) were measured in the final dry powder of this alga using atomic absorption spectroscopy. The content of As, Cd, Hg and Pb in the dry powder were very low and they ranged between 0.002 mg kg^{-1} for As and 0.109 mg kg^{-1} for Pb. Higher levels were found for Cu, Fe, Mn and Zn and they varied between 8.51 mg kg^{-1} for Cu and 394 mg kg^{-1} for Fe. The results indicated that the heavy metal content of Saudi Arabian *Spirulina* is within the recommended range established by major producers.

Key words: *Spirulina*, heavy metal content, Saudi Arabia

INTRODUCTION

The microalga (cyanobacterium) *Spirulina* (*Arthrospira*) is one of the most important microorganisms due to its suitable content of protein, vitamins, minerals, pigments and phytonutrients. *Spirulina platensis* was the first cyanobacterium to be commercially cultivated using modern biotechnology (Hu, 2004). It has been used as a food supplement for human and animal nutrition (Ciferri, 1983; Jassby, 1988a; Richmond, 1988; Belay, 1997; Al-Batshan *et al.*, 2001; Becker, 2004). The final product of *Spirulina* must meets the quality criteria set by different producers and organizations in order to be used as a food supplement in local and international markets (Jassby, 1988b; Becker, 1988, 1994, 2004; Belay, 1997).

In Saudi Arabia, the interest in *Spirulina* started in 1999 when the Arabian Agricultural Service Company (ARASCO) established a small farm of this microalga (Al-Homaidan, 2002). The effects of the dry powder of this farm on chicken macrophage phagocytic function and nitrite production were examined (Al-Batshan *et al.*, 2001). The impacts of temperature, pH and salinity on the growth and protein content of two locally isolated species of *Spirulina* were studied (Al-Homaidan *et al.*, 2005). Sabbagh (2006) studied the effects of cadmium, copper, lead and uranium on chlorophyll, DNA, protein content and ultrastructure of *S. platensis.* He also measured the heavy metal content of five edible algae collected from Riyadh health food stores.

The purpose of this study was to determine the heavy metal concentrations in a locally grown strain of *S. platensis* and to decide whether or not this *Spirulina* is suitable as a food and feed supplements in Saudi Arabia and other markets.

MATERIALS AND METHODS

***Spirulina* culture:** *Spirulina platensis* strain was acquired from the university of Texas at Austin, U.S.A. (UTEX No. LB 2340). It was propagated in the laboratory using the modified Zarrouk medium (Vonshak, 1997a). Outdoor mass cultures were carried out according to the methods described by Gupta and Changwal (1992), Venkataraman and Mahadevaswamy (1992), Becker (1994), Fox (1996), Belay (1997), Vonshak (1997b) and Al-Homaidan (2002). They were conducted in 200-500 m^2 oblong raceway ponds lined with polyvinylchloride plastic. The cultures were enriched with a commercial compound fertilizer containing equal amounts of N, P and K and less than 0.1% of micronutrients. The concentration of the Sodium bicarbonate which was added to the cultures was between 13 and 14 mg L^{-1}. The culture depth was maintained at 10-12 cm by daily addition of enriched freshwater. Paddle wheels were used to circulate the water at a speed of about 30 cm sec^{-1}. Harvesting was carried out by filtration through nylon filters (150-200 mesh). The biomass slurry was rinsed in acid water at pH 4.0 followed by freshwater. Drying was conducted under direct sunlight.

Sample preparation for atomic absorption spectroscopy: Algal samples were air dried at 90°C and 50 mg of the air dried samples were placed into digestion tubes. Twenty mL of concentrated nitric acid was added to each tube and the contents of the tubes were digested at 120°C for about 2 h. After cooling, 20 mL of double distilled water was added to each tube and the content was filtered through 0.45 μm millipore filters. The solutions were transferred to 25 mL volumetric flasks and the volumes were completed to 25 mL with double distilled water. Concentrations of As, Cd, Cu, Fe, Hg, Mn, Pb and Zn were determined in these aliquot samples (Lajunen, 1992; Sadiq and Zaidi, 1994). Two models of Shimadzu atomic absorption spectrometers were used for the measurement of metals. These were AA-6650F flame AAS with auto sampler and AA-6650G controlled furnace AAS with hydride vapor generator.

RESULTS AND DISCUSSION

The average concentrations of As, Cd, Hg and Pb are shown in Table 1. Very low levels were found for these highly toxic non-essential metals. The concentration averages found for each contaminant, expressed in mg kg^{-1} dry weight, were as follows; As, 0.002; Cd, 0.031; Hg, 0.008; Pb, 0.109. Higher concentrations were obtained for the essential metals. The average concentrations of Cu, Fe, Mn and Zn, expressed in mg kg^{-1} dry weight, were 8.51, 394.0, 27.88 and 21.81, respectively (Table 2). Elevated amounts of heavy metals in algal biomass is one of the major problems that limit the large-scale utilization of microalgae (Jassby, 1988b; Becker, 1994). According to Becker (2004), no official standards exist for heavy metal levels in microalgal products. Some of the algal major producers have established their own guidelines for the heavy metal content of their microalgal products. For instance, guidelines for the concentrations of As, Cd, Hg and Pb in *Spirulina* were adopted by the major producers in different countries around the world (Boudene, 1975; Belay, 1997; Torres-Duran *et al.*, 1998). A comparison between these levels and the heavy metal content of Saudi Arabian *Spirulina* is presented in Table 1. It can be seen that the heavy metal concentrations in the locally produced *Spirulina* is much lower than the guidelines established by major producers and it can be said that the local *Spirulina* will not cause any toxicological effects on consumers. Another comparison also can be made between the Cd and Pb contents of the local *Spirulina* and that obtained from Riyadh health food stores. Sabbagh (2006) found out that the concentrations of Cd in two brands of imported *Spirulina* ranged between 0.06 and 0.08 mg kg^{-1} and at the same time the Pb levels in these two samples varied between 0.13 and 0.26 mg kg^{-1}. These levels are much higher than the concentrations found in this study.

The essential elements Cu, Fe, Mn and Zn are required in low concentrations by all kinds of life because they play important roles in metabolic processes taking place in living cells (Botkin and Keller, 2005). However, elevated levels of these elements are toxic to most organisms (Kaplan, 2004). To the author knowledge, no guidelines for the levels of these metals in microalgal products have been established by any major producer. By comparing the findings of this study with Earthrise Farms, which are the world largest *Spirulina* producers (Table 2) it is possible to say that the Saudi Arabian *Spirulina* content of Cu, Fe, Mn and Zn are within the expected limits for this alga. Similar conclusion will be achieved by comparing the results of this study with that of Jassby (1988a).

Table 1: As, Cd, Hg and Pb content of Saudi Arabia Spirulina in relation to international standards (data given in mg kg^{-1})

	As	Cd	Hg	Pb
Saudi Arabia	0.002	0.031	0.008	0.109
USA (Belay, 1997)	<1.0	<0.05	<0.05	<1.0
India (Torres-Duran *et al.*, 1998)	1.1	1.0	0.1	2.5
Mexico (Boudene *et al.*, 1975)	2.9	0.5	0.5	5.1

Table 2: Cu, Fe, Mn and Zn content of Saudi Arabia *Spirulina* in relation to Earthrise Farms (data given in mg kg^{-1})

	Cu	Fe	Mn	Zn
Saudi Arabia	8.51	394	27.88	21.81
Earthrise Farms (Belay, 1997)	12	1,000	50	30

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