Investigation of Physicochemical, Nutritional, Textural, and Sensory Properties of Iranian Yazdi Cupcake Enriched with Spirulina (Arthrospira platensis)

Mohammad-Taghi Golmakani*, Mahsa Moayyedi, Aida Raiissjalali, Yasaman Pesaran, and Abdolreza Aghajani

Abstract—Microalgae Spirulina (Arthrospira platensis), has been the subject of intense investigations because of its use as food, dietary supplement and functional food. Spirulina is a rich source of proteins, vitamins, minerals, antioxidants, essential amino acids and fatty acids. In this study, Spirulina powder was incorporated in to the formulation of Iranian Yazdi cupcake at different concentrations of 0.5, 1.5 and 2.5%. Also, equal amounts of cinnamon powder were added to formulations for improving flavor. The results showed that protein and ash contents increased by increasing Spirulina concentration. The lowest hardness and chewiness were observed for the treatment containing the highest concentration of Spirulina. Color parameters (L*, a*, and b*) of cupcakes decreased by increasing Spirulina concentration. According to sensory evaluation results, there were no significant differences among different treatments in general acceptance. The results showed that application of microalgae Spirulina can improve nutritional, physicochemical and textural properties of cupcakes.

Keywords—Arthrospira platensis, Spirulina, Texture, Yazdi Cupcake

I. INTRODUCTION

Today, the consumers prefer low-calorie, low-fat, and low-cholesterol ready-to-eat foods, namely healthy foods and are aware of the relationship between diets and disease development. Given the efforts made to reduce the incidence of diseases such as cancers, cardiovascular, coronary heart disease and to improve the health status, development of foods rich in vegetable and anticancer compounds may play a major role in securing the health of consumers [1]. Among baked products, cakes are especially popular being perceived as a delicious product with special organoleptic properties [2].

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Cakes are produced in various types being a favorite food especially among children and juveniles. It is a kind of sweet with a special soft, texture being classified as a baked product. Its main ingredients include flour, oil (except for sponge cake), sugar, and eggs [3]. Cake production in Iran amounted 400,000 ton in 2007 and it reached 630,000 ton in 2014 [4]. Cakes are classified into three groups: oil cake, sponge cake, and whole cake. Oil cakes must have uniform texture and color, desirable taste and aroma with no spots, exogenous flavor and smell. The most important and well-known Iranian oil cake is Iranian Yazdi cupcake [3]. Long-term consumption of cakes results in obesity and the consequent problems since cakes are made with a high amount of fat and sugar providing high level of energy and calorie [5]. Thus, addition of healthful components and functional nutrients to the formulation of cakes, namely fortification technique, play a significant role in reducing the risks associated with fat and sugar consumption [6].

Microalgae are photosynthetic prokaryotic or eukaryotic microorganisms which produce carbohydrates, proteins, and lipids through photosynthesis process [7]. Microalgae are grown as a good source of polyunsaturated fatty acids, pigments, antioxidants and therapeutically bioactive compounds. They also contain essential fatty acids such as linoleic, arachidonic, linolenic, and gamma-linolenic acids, [8] different vitamins (B complex group and ascorbic acid) as well as minerals (potassium, sodium, magnesium, iron, and calcium). Also, suitable components for feed supplementation of some species of microalgae contain more vitamins than cultivated plants [6]. Among well-known algae species, Chlorella vulgaris and Arthrospira platensis (Spirulina) are common safe edible microalgae. Spirulina introduced by food and drug administration (FDA) as generally recognized as safe (GRAS) [9]. It is rich in nutrients and contains all essential amino acids [10]-[11] high - quality protein, vitamins B2, B6, B12 (more than that of bovine liver), A, E, and K as well as calcium and iron [12]. The pattern of amino acid, carbohydrate, and fatty acids of Spirulina is corresponded with that of other foods [13]. About 0.5-3 g Spirulina per meal is recommended [14]. Antioxidant property of Spirulina is largely attributed to C-phycocyanin, beta-carotene, and phenolics [15].

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Addition of this functional microalga to food products such as cake, biscuit, and cookies may promote the health status and prevent malnutrition among children [16]. The aim of this study was to enrich Yazdi cupcakes with different levels of *A. platensis* powder to improve its quality properties and nutritional values.

II. MATERIALS AND METHODS

*A. platensis* (Spirulina) powder was purchased from Sina microalgae company, Qeshm, Iran. It was kept in a dry and cool place away from light. The equipment used in this study included TPA Texture Analyzer (Brookfield CT3, UK), atomic absorption spectroscopy (Model AA-670G, Shimadzu, Japan), Soxhlet system (model P-sc, US), micro-Kjeldahl (peco, Iran), electric furnace (Accation, model Atash 1200, Iran), digital camera (1/12 Mpixel, canon, model powershot SX270, HS, Malaysia), and ICP (Model VISTA –PRO, Varian, Simultaneous ICP-OES, US).

A. Cupcake Preparation

The ingredients required for making Yazdi cupcake included flour (1.5 kg), sugar (1.100 kg), eggs (5), liquid oil (500 g), yoghurt (350-400 g), rose water (250 g), sodium bicarbonate (30 g), sugar syrup (125 g), cinnamon (2.5 g), water (as required amount) and Spirulina (0.5, 1.5, and 2.5 (% w/w)). First, sugar syrup and eggs were mixed for 2 min at medium speed to produce a nearly consistent cream white foam to which yoghurt was added and mixed for 2 min. The flour and sodium bicarbonate mixture was added and mixed thoroughly. Finally oil, rosewater, and water were added. The prepared dough was placed in non-stick mold, and baked in oven at 250°C for 20 min till the crust became golden. The baked cupcakes were removed from molds and cooled to ambient temperature of 30°C. Finally, they were packed in thick polyethylene bags and heat-sealed. The treatments are given in Table I.

### TABLE I

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Cupcake sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Sample without Cinnamon and Spirulina (control)</td>
</tr>
<tr>
<td>B</td>
<td>Sample with Cinnamon and without Spirulina</td>
</tr>
<tr>
<td>C</td>
<td>Sample with Cinnamon and Spirulina at 0.5%</td>
</tr>
<tr>
<td>D</td>
<td>Sample with Cinnamon and Spirulina at 1.5%</td>
</tr>
<tr>
<td>E</td>
<td>Sample with Cinnamon and Spirulina at 2.5%</td>
</tr>
</tbody>
</table>

B. Chemical Analysis

Moisture (according to Iranian National Standard No. 2705), ash (using electric furnace, Standard No. 37), fat (using Soxhlet system, Standard No. 2862), and protein contents (using micro-Kjeldahl system, Standard No. 2863) were measured. Minerals (manganese, magnesium, calcium, iron, and selenium) of cupcake samples were measured by using Atomic Absorption spectroscopy (Standards No. 975-03, 1990, AOAC).

C. Physical Analysis

In order to evaluate the color and determine the colorimetric parameters (b, a, L) of crust and crumb, digital camera and Photoshop software were used. Yellowness and blueness were represented by b* as b' and b represent yellowness and blueness, respectively. Greenness and redness were represented by a* as a’ and a' indicate redness and greenness, respectively. L* indicates brightness as L=100 indicates whiteness and L=0 represents blackness. The samples were placed in a cardboard container of which some pictures were taken by digital camera. The images were then checked by Photoshop Software. a*, b*, and L* parameters were determined by selecting a certain area from the center of each sample [17].

D. Texture Analysis

To conduct TPA compression test, some pieces of different treatments (2 × 2 × 2 cm³) were cut. Different parameters including hardness (gradient between two points of power-time curve at first pressure), resilience (max power per contact), gumminess (Max power multiplied by cohesiveness value), chewiness (springiness multiplied by gumminess value), cohesiveness (level 2 divided by level 1), and springiness (returning to an original shape when pressed down) were measured (by texture profile analysis, TPA).

E. Sensory Analysis

Organoleptic hedonic analyses were used to evaluate cupcake samples. Twenty trained panelists (10 males and 10 females aged 20-40) were selected for sensory evaluation of cupcake samples. The panelists were asked to assess sensory properties of cupcake samples including color, texture, flavor, taste, and total acceptance and record the quality scores on the respective form. A 9-point scale was used for the sensory evaluation: (1) very bad, (2) bad, (3) poor, (4) relatively poor, (5) intermediate, (6) good, (7) very good, (8) excellent, and (9) very excellent.

F. Statistical Analysis

Data were analyzed by SAS software (version 9.1) in triplicate based on generalized linear model (GLM) using least significant difference (LSD) for mean comparison at 95% level.

III. RESULTS AND DISCUSSION

A. Chemical Analysis

The results of chemical analyses are given in Table II. As shown in Table II, samples A and B had the highest and the lowest moisture contents, respectively. However, there was no significant difference between samples containing 0.5, 1.5, and 2.5% microalgal powder. The reports have revealed that hydrophilic colloids present in Spirulina reduced moisture loss during storage. In other words, protein molecules of Spirulina show an anti-staling effect over storage. Thus, it is evident that this microalga extends the shelf-life of the product [18]. In the present study, the sample without cinnamon and Spirulina had the highest moisture content. In the other study, application of
Spirulina biomass at concentrations of 1 and 2% together with 2 and 4% cassava bran retained more moisture in comparison with control sample (without microalgae and bran) [19]-[20]. The treatments showed no significant difference in fat content (Table II). Treatment D and E showed the highest amounts of protein content. Protein content of most algae is higher than that of other proteinaceous foods both in amino acids content and essential amino acid supply for body [21].

Some researchers showed that Spirulina may be used in bakery products for protein enrichment without any significant changes in texture [22]. According to our findings, Danesi et al. (2004) found that cake samples enriched with 2% Spirulina and 4% cassava bran had higher protein content (4.3%) in comparison with the samples containing 1% microalgae and 2% bran (3.9%), as well as control (2.8%). Also, Salehifar et al. (2012) added Spirulina at concentrations of 0, 0.5, 1, and 1.5% (w/w) to the formulation of cookies and stated that the fortified cookies had significantly higher protein content. On the other hand, high protein content (46-63%) in dried biomass of Spirulina is the main interesting property [23]. Its protein is highly digestible because of lacking cell wall [24]. In a study the addition of this microalgae to the cookies significantly increased the protein content of fortified samples in comparison with control [25].

### Table II

<table>
<thead>
<tr>
<th>Cupcake sample</th>
<th>Moisture (%)</th>
<th>Fat (%)</th>
<th>Protein (%)</th>
<th>Ash (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>25.4</td>
<td>12.50</td>
<td>7.323</td>
<td>0.85</td>
</tr>
<tr>
<td>B</td>
<td>23.8</td>
<td>12.00</td>
<td>7.263</td>
<td>1.03</td>
</tr>
<tr>
<td>C</td>
<td>22.4</td>
<td>12.20</td>
<td>8.330</td>
<td>1.04</td>
</tr>
<tr>
<td>D</td>
<td>22.6</td>
<td>12.07</td>
<td>8.578</td>
<td>1.11</td>
</tr>
</tbody>
</table>

In each column different letters are significantly different (p<0.05).

Table III shows the amount of Mn, Mg, P, Ca, Fe, and Se (%) in cupcake samples enriched with Spirulina. Iron is a vital micronutrient in human nutrition which its deficiency leads to iron-deficiency anemia. Spirulina is a good source of iron [26]. According to Table III, the treatment containing 2.5% Spirulina had the highest Fe content among other samples. Fe contents of cupcake samples increased by increasing Spirulina concentration. This finding is in accordance with the results of study conducted on the cookies enriched with Spirulina [25].

### Table III

<table>
<thead>
<tr>
<th>Cupcake sample</th>
<th>Mn (%)</th>
<th>Mg (%)</th>
<th>P (%)</th>
<th>Ca (%)</th>
<th>Fe (%)</th>
<th>Se (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>32.30</td>
<td>153.8</td>
<td>800.0</td>
<td>270.6</td>
<td>60.23</td>
<td>0.36</td>
</tr>
<tr>
<td>B</td>
<td>34.00</td>
<td>152.7</td>
<td>792.5</td>
<td>270.5</td>
<td>65.06</td>
<td>0.38</td>
</tr>
<tr>
<td>C</td>
<td>35.27</td>
<td>182.45</td>
<td>871.5</td>
<td>326.80</td>
<td>73.20</td>
<td>0.39</td>
</tr>
<tr>
<td>D</td>
<td>36.00</td>
<td>212.25</td>
<td>947.0</td>
<td>426.59</td>
<td>81.60</td>
<td>0.42</td>
</tr>
<tr>
<td>E</td>
<td>36.83</td>
<td>251.25</td>
<td>1080.0</td>
<td>524.44</td>
<td>103.63</td>
<td>0.44</td>
</tr>
</tbody>
</table>

In each column different letters are significantly different (p<0.05).

E and A treatments had the highest and lowest Mn content, respectively. There was no significant difference between B and C. Treatment containing 2.5% Spirulina had the highest amount of minerals indicating the importance of microalgae used in the formulation of Yazdi cupcake. Branger et al. (2003) found that the formulation of cakes enriched with Spirulina had higher ash content due to the presence of Fe, Ca, K, P, Mn, Cu, Zn, Mg, Bo, Mo, and Se contained in the microalgae. Prabhasankar et al. (2009) enriched Semolina pasta with different levels of Volkama algae. Volkama algae powder significantly increased protein, fat, ash, and fiber contents. Treatment containing cinnamon and 2.5% microalgae had the highest ash content because of the presence of significant amount of Mg, Fe, Ca, P, Mn, and Se.

### B. Physical Analysis

Spirulina with primary pigment of chlorophyll a and secondary pigment of phycobilis protein may be useful as a natural green material with high stability [27]. There is an increasing interest in natural colors in foods and pharmaceuticals because of reported toxic efforts of synthetic colors. Since, today synthetic sources are increasingly replaced by natural ones such as cyanobacteria especially Spirulina in foods, medicines and cosmetics [28]. The results of measuring crumb and crust of cupcake samples enriched with Spirulina are presented in Figures 1 and 2, respectively. The results revealed that L*, a*, and b* values significantly (p<0.05) decreased in cuprum by increasing the microalgae level. The reason for reduced brightness may be related to the green and green-blue chlorophyll pigments as well as phycocyanin contained in microalgae which was substituted partly with flour. Gouveia et al. (2007) investigated the effect of using microalgae *C. vulgaris* on Korean traditional cookies. They found greenness of the cookies containing 1% (w/w) *C. vulgaris* showed the maximum stability during 3-month storage.

Increasing Spirulina concentration significantly (p<0.05) reduced the color parameters in crust. It is in accordance with the result obtained by Fradique et al., (2010) that increased level of microalga Spirulina and *C. vulgaris* in the formulation of spaghetti reduced b* parameter value. Also, it was concluded that the addition of *C. vulgaris* intensified the color of biscuits. The parameters value decreased as the level of microalgae increased in the sample [18]. The apparent colors of the cupcake samples fortified with Spirulina are shown in Figure 3.
gumminess and chewiness both are affected by hardness. The lowest hardness, chewiness, and gumminess were found for the treatment containing the highest concentration of microalgae. Table IV shows the parameters obtained by TPA for cupcake samples enriched with Spirulina. As shown in Table IV, the highest chewiness springiness, gumminess and cohesiveness were observed for the treatment containing cinnamon (1 and 1.5%) Spirulina. The lowest hardness, chewiness, and gumminess were found for the treatment containing the highest amount of microalgae (2.5%). According to the results of TPA, increased level of Spirulina was found to cause an increase in the firmness of Korean traditional cookies [18]. In another research, gel elasticity module increased by increasing the concentration of Spirulina protein isolate according to electrostatic and hydrogen bonds during gel formation [11].

Another reason is the effect of microalgae on dough bubbles as high concentration of microalgae may result in increased firmness [32].

C. Texture Analysis

In TPA, two variables i.e. chewiness and gumminess are respectively defined as the required energy for oral digestion of a solid food and for decomposition of a semi-solid food for its ingestion [29]. Table IV shows the parameters obtained by TPA for cupcake samples enriched with Spirulina. As shown in Table IV, the highest chewiness springiness, gumminess and hardness were observed for the treatment containing cinnamon without microalgae. The lowest hardness, chewiness, and gumminess were found for the treatment containing the highest amount of microalgae (2.5%). According to conducted studies, gumminess and chewiness both are affected by hardness [30]. In contrast to other microalgae, prokaryotic Spirulina cells lack hard cell wall resulting in accelerated water uptake by cell contents notably proteins. Indeed, protein molecules of Spirulina compete with starch molecules for water-binding sites due to their hydrophilicity leading to instability of starch gelation mechanism thereby retarding it and improving the texture of final product [31].

D. Sensory Analysis

Table V shows the effect of microalgae and cinnamon on sensory evaluation of cupcakes enriched with Spirulina. Although the highest scores were given to treatment B (Yazdi cupcake with cinnamon and without microalgae) and the lowest scores were given to 2.5% Spirulina treatment for all parameters by the panelists, the obtained results are not significantly different unless for color due to the microalgae effects on brightness of the cupcakes. Also, Danesi et al. (2010) reported that bakery products can be enriched with Spirulina regarding protein content without any adverse effect on sensory acceptance of the product. Also, in the study conducted by Salehifar et al., different concentrations of Spirulina were added to the formulation of cookies. The result of hedonic scale showed the highest scores for cookies containing 1 and 1.5% Spirulina.

### Table IV

<table>
<thead>
<tr>
<th>Cupcake samples</th>
<th>Hardness (g)</th>
<th>Cohesiveness (g)</th>
<th>Springiness (g)</th>
<th>Gumminess (g)</th>
<th>Chewiness (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>489.50&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.60&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.912&lt;sup&gt;a&lt;/sup&gt;</td>
<td>294.70&lt;sup&gt;a&lt;/sup&gt;</td>
<td>263.501&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>B</td>
<td>560.50&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.55&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.918&lt;sup&gt;a&lt;/sup&gt;</td>
<td>306.10&lt;sup&gt;a&lt;/sup&gt;</td>
<td>275.500&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>C</td>
<td>451.00&lt;sup&gt;bc&lt;/sup&gt;</td>
<td>0.54&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.907&lt;sup&gt;b&lt;/sup&gt;</td>
<td>243.80&lt;sup&gt;b&lt;/sup&gt;</td>
<td>216.600&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>D</td>
<td>483.00&lt;sup&gt;cd&lt;/sup&gt;</td>
<td>0.54&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.883&lt;sup&gt;b&lt;/sup&gt;</td>
<td>294.70&lt;sup&gt;b&lt;/sup&gt;</td>
<td>263.501&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>E</td>
<td>417.50&lt;sup&gt;c&lt;/sup&gt;</td>
<td>0.57&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.893&lt;sup&gt;c&lt;/sup&gt;</td>
<td>236.70&lt;sup&gt;b&lt;/sup&gt;</td>
<td>207.202&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

In each column different letters are significantly different (p<0.05).

The highest cohesiveness was observed for control sample. According to the results of TPA, increased level of Spirulina in the formulation of Yazdi cupcake reduced hardness, chewiness, and gumminess. This finding is in consistent with the results of Marchylo et al. (2004) that the addition of optimum levels of Spirulina species resulted in reduced hardness of cookies, cakes, and pasta. In contrast, C. vulgaris was found to cause an increase in the firmness of Korean traditional cookies [18]. In another research, gel elasticity module increased by increasing the concentration of Spirulina protein isolate according to electrostatic and hydrogen bonds during gel formation [11].

### Table V

<table>
<thead>
<tr>
<th>Cupcake samples</th>
<th>Crust texture</th>
<th>Crumb texture</th>
<th>Crust color</th>
<th>Crumb color</th>
<th>Aroma and flavor</th>
<th>General acceptance</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>8.30&lt;sup&gt;a&lt;/sup&gt;</td>
<td>7.95&lt;sup&gt;a&lt;/sup&gt;</td>
<td>6.70&lt;sup&gt;c&lt;/sup&gt;</td>
<td>7.45&lt;sup&gt;b&lt;/sup&gt;</td>
<td>5.30&lt;sup&gt;a&lt;/sup&gt;</td>
<td>7.55&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>B</td>
<td>8.45&lt;sup&gt;a&lt;/sup&gt;</td>
<td>8.25&lt;sup&gt;a&lt;/sup&gt;</td>
<td>8.25&lt;sup&gt;a&lt;/sup&gt;</td>
<td>8.70&lt;sup&gt;a&lt;/sup&gt;</td>
<td>8.55&lt;sup&gt;a&lt;/sup&gt;</td>
<td>8.50&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>C</td>
<td>8.30&lt;sup&gt;a&lt;/sup&gt;</td>
<td>8.30&lt;sup&gt;a&lt;/sup&gt;</td>
<td>7.50&lt;sup&gt;a&lt;/sup&gt;</td>
<td>8.10&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>8.15&lt;sup&gt;a&lt;/sup&gt;</td>
<td>8.20&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>D</td>
<td>8.15&lt;sup&gt;a&lt;/sup&gt;</td>
<td>8.25&lt;sup&gt;a&lt;/sup&gt;</td>
<td>7.45&lt;sup&gt;b&lt;/sup&gt;</td>
<td>7.50&lt;sup&gt;a&lt;/sup&gt;</td>
<td>8.20&lt;sup&gt;a&lt;/sup&gt;</td>
<td>8.20&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>E</td>
<td>7.90&lt;sup&gt;a&lt;/sup&gt;</td>
<td>7.80&lt;sup&gt;a&lt;/sup&gt;</td>
<td>7.35&lt;sup&gt;b&lt;/sup&gt;</td>
<td>7.45&lt;sup&gt;b&lt;/sup&gt;</td>
<td>7.95&lt;sup&gt;a&lt;/sup&gt;</td>
<td>8.10&lt;sup&gt;ab&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

In each column different letters are significantly different (p<0.05).
IV. CONCLUSION

Addition of microalgae Spirulina as functional food supplement can provide valuable nutritional properties regarding iron and calcium content. In the present study, the highest level of microalgae had the highest content of ash, protein, Mn, Mg, and Se in comparison with the control. The lowest hardness, gumminess, and chewiness were observed for the treatment containing the highest level of microalgae (2.5%). The results of sensory evaluation showed that treatments containing Spirulina were not significantly different from control. In addition, the color of treatment was acceptable by the panel in spite of slight darkness. It may be concluded that Yazdi cupcakes enriched with Spirulina powder could be marketed and be appealing for consumers for their high nutritional value, desirable texture, and flavor.

REFERENCES


