Sensory Descriptive Analysis and Physicochemical Properties of *Spirulina platensis* from Different Drying Processes: Hot Air Drying and Microwave Vacuum Drying

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Abstract

This research compared the sensory and physicochemical characteristics of dried Spirulina (*Spirulina platensis*) using hot air drying (50ºC, 8 h) versus microwave vacuum drying (4800 watts, 40 min). Ten trained panelists received three months of training in terminology development, reference selection, intensity scaling (15 centimeter line scale) and warm up sample before conducting generic descriptive analysis. The sensory descriptive results identified 16 attributes of dried Spirulina: green-yellow color, particle size, four odors (fish, salty, seaweed, green), three tastes (salt, bitter, umami), three flavors (chicken, fish, algae) and four aftertastes (oily, bitter, pork, astringent). The method of drying (hot air versus microwave vacuum drying) affected the moisture content, color value (L*, a* and b*), total antioxidant activity, total phenolic compounds, color attribute, fishy odor, and seaweed odor of dried Spirulina with significant difference ($p \leq 0.05$). Microwave vacuum drying provided better color and aroma than the hot air drying ($p \leq 0.05$). The intensities of green-yellow color, fishy odor, and seaweed odor of Spirulina from hot air drying were 8.32±0.93, 5.83±0.77 and 8.10±0.51, respectively. Those from microwave drying were 5.27±0.80, 6.97±0.52, and 6.58±0.82, respectively. However, the taste, flavor and aftertaste of both dried Spirulinas did not differ significantly ($p \geq 0.05$). Nevertheless, the lower of total antioxidant activity and total phenolic compounds loss of dried Spirulina samples were found in sample from microwave vacuum drying. The two different drying methods used affected the physicochemical and sensory characteristics of dried Spirulina.

Keywords: *Spirulina platensis*, descriptive analysis, hot air drying, microwave vacuum drying

1. Introduction

Spirulina platensis is a blue-green Cyanobacterium, owing to the presence of both chlorophyll (green) and phycocyanin (blue) pigments in its cellular structure [1]. Spirulinacan live in either fresh or saltwater. It is produced commercially worldwide, and the dry product is a valuable food supplement. Spirulina is rich in protein (60-70% by dry weight), vitamins and minerals; contains many essential amino acids and fatty acids [2]; and is an expensive source of pigment for the cosmetics industy [3]. Spirulina was used as a nutritional supplement for humans and animals, and

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as well as source of active metabolite in the pharmaceutical [4]. In vitro and in vivo studies have shown that Spirulina can effectively treat cancer and allergies, viral and candiovascular diseases, hepatotoxicity, hyperglycaemia, and inflammation [5]. The polyunsaturated fatty acids and pigments in Spirulina have antioxidant properties [6].

The objective of drying foods is the remove of water from solids, helping to minimize microbial growth and chemical deterioration; this is an important option in food manufacturing [7]. Many drying methods, including oven drying, freeze-drying, and microwave drying, have been used to preserve Spirulina. Previous research has shown that spray and convective drying of Spirulina reduces its antioxidant capacity by one-half [8]. This microwave vacuum drying method has benefits of microwave vacuum drying Spirulina; however, to date, the studies have mainly focused on the effect of drying method on the phenolic content and antioxidant capacity, rather than the sensory characteristics of Spirulina.

Many sensory programs have been developed specifically for QC/QA purposes [9]. Sensory evaluation is the only method that provides integrated, direct measurements of perceived intensities of target sensory attributes of products. Key or target attributes should relate to consumer acceptance and purchase behavior [10]. This research compared the effects of hot air versus microwave vacuum drying of Spirulina (*Spirulina platensis*) on the dried product in terms of total antioxidant activity, total phenolic compounds and sensory characteristics.

2. Materials and Methods

2.1 Fresh Spirulina sample

The fresh Spirulina (*Spirulina platensis*) sample was harvested from the Green Diamond Co., Ltd. (Chiang Mai, Thailand), located in northern Thailand. The fresh Spirulina was stored in aluminum foil bags at 4ºC until used in the experiment. The fresh Spirulina was analyzed for moisture content, crude protein, crude fat, crude fiber, ash, total antioxidant activity and total phenolic compounds.

2.2 Biomass Drying

Spirulina sample was dried using two different methods: hot air and microwave vacuum drying. For hot air drying, the dryer was set at 50 ºC and the samples were dried approximately 8 hours or until their moisture content were lower than 0.10 kg kg^{-1} (wet basis) [2]. The microwave vacuum drier was set at 4800 watt for 40 min. The thickness of sample was 3 mm. The dried samples were ground on a knife mill and sieved (150 mesh), packed in aluminum foil bags and stored in a desiccator at ambient temperature.

2.3 Physicochemical analysis

The color of the *Spirulina* samples was measured using a Minolta colorimeter (CR-410, Konica-Minolta, Japan) in CIE Lab system (L*,a* and b*) calibrated by standard plate of white surface.

Moisture, crude protein (NX 6.25), crude fat and crude fiber content of fresh Spirulina were analyzed by AOAC method [11]. The Spirulina (1g) was extracted with 10 mL of 70% ethanol for 60 min at room temperature and then centrifuge at 6000 rpm at 4ºC for 15 min, after which the supernatant was separated from the residue and stored at -4 ºC until analysis.

The total antioxidant activity of Spirulina was determined by the DPPH assay according to Brand-Williams *et al.* [12] with some modifications. Each sample of ethanol extract (0.1 mL) was mixed with 3.5 mL of 0.06 mM DPPH (1,1-diphenyl-2-picrihigrazil) ethanol solution, then incubated for 30 min in a dark room at room temperature. The measurements were carried out on a spectrophotometer (UV-vis model 1601, Shimadzu, Japan) at a wavelength of 515 nm. The results were expressed as milligrams of Gallic acid equivalent (GAE) per 100 grams of dry basis.

The total antioxidant activity of Spirulina was determined by Ferric reducing antioxidant power according to Sudha *et al.* [13]. The FRAP reagent consisted of 300 mM acetate buffer, 10 mM TPTZ in 40 mM HCL and 20 mM $FeCl_3.6H_2O$ in the ratio of 10:1:1. Freshly prepared and pre-warmed (37ºC) of FRAP reagent (1.5 mL) was added in a test tube containing 50 µL of extanol extracted samples and then incubated at 37ºC for 10 min. The absorbance was read against reagent blank (1.5 mL FRAP reagent + 50 µL distilled water) at 593 nm. The results were expressed as milligrams of ferric ions reduced per 100 grams of dry basis.

The total phenolic compounds of Spirulina was determined according to Assis *et al.* [14]. A sample of ethanol extract (0.1 mL) was mixed with 1.6 mL of 7.5% sodium carbonate and 2 mL of Folin-Ciocalteu's reagent. The reaction mixture was left for 30 min. in a dark room at room temperature. The absorbance was recorded at 765 nm. The results were expressed as milligrams of Gallic acid equivalent (GAE) per 100 grams of drybasis.

2.4 Descriptive sensory analysis

The test of dried Spirulina samples were conducted in an environmentally-controlled sensory laboratory with partitioned booths at Chiang Mai University. Descriptive analysis employed the generic descriptive analysis method. Atrained descriptive sensory panel (10 panelists) was recruited from staff and students with sensory experience at the Department of Product Development Technology, Chiang Mai University, Chiang Mai University, Chiang Mai, Thailand. These training sessions, approximately 2 hours each, were conducted over an 8-day period. Panelist evaluated the dried Spirulina and listed the sensory attributes and descriptors for their appearance, aroma, taste, flavor, and aftertaste. References of each attribute were generated and consensus by train panelists. Panelists also determined references to use during evaluations to help them evaluate the appearance, aroma, taste, flavor, and aftertaste. Each panelist rated the intensity of each attribute by first evaluating the reference for that particular attribute, and then giving an intensity rating, with each attribute placed adjacent to a 15-cm horizontal line, anchored one-half inch (13 mm) from each end with directional terms (e.g., weak/strong, slightly/very). Each trained panelist rated the attributes of two dried Spirulina samples.

2.5 Statistical analysis

Statistical analysis was conducted using SPSS 17.0 (SPSS Inc., IBM Corp., IL, USA) for the analysis of variance (ANOVA) in determining significant differences between drying methods at a confidence level at 95% ($p \leq 0.05$). Variable means were compared using Duncan's multiple range test. For descriptive analysis, independent sample t-test was used to determine significant differences between two dried Spirulina samples at a confidence level at 95% ($p \leq 0.05$).

3. Results and Discussion

3.1 Physicochemical composition of fresh *Spirulina platensis*

The physicochemical composition of the fresh *Spirulinaplaensis* in dry basis was moisture content 81.38±2.07 crude protein content 69.96±2.00 crude fat content 0.65±0.17 crude fiber content 2.18±0.55 and ash 5.27±0.55 in percentage. The total antioxidant activity by DPPH assay, total antioxidant activity by FRAP assay and total phenolic compounds were 69.82 ± 13.16mgGAE $100g^{-1}$, 1585.35 ± 45.96 mgFeSO4 $100g^{-1}$ and 371.43 ± 32.57 mgGAE $100g^{-1}$, respectively. The color values L*, a* and b* of dried Spirulina samples were 23.22 ± 0.23, -1.55 ± 0.1 and 4.22 ± 0.26, respectively. A prior report has shown that *Spirulina platensis* has a high protein concentration (60-70% of dry weight), whose nutritive value is related to the quality of amino acid [15].

3.2 Effect of drying method on physicochemical composition

The result showed no significant different ($p \geq 0.05$) between drying methods on the moisturecontent. The overall color parameters of Spirulina are affected by the drying methods ($p \leq 0.05$). The L* a* and b* values of dried Spirulina from the microwave vacuum drying were higher than the hot air drying (Table 1). Which indicated that dried Spirulina from the hot air drying darker color less yellow and red than the microwave vacuum drying. The color became darker implying that more browning of the product occurred while less yellow color could imply that pigment destruction had occurred [16]. Authors report higher darkening of the sample at higher drying air temperature for long time [4].

Table 1. Comparison of the moisture and color values of fresh, hot-air dried, and microwave-vacuum dried Spirulina samples.

Treatment	Moisture	L*	a*	b*
Microwave drying	4.47±0.90^{b}	42.44±0.71^{a}	-2.82±0.07^{b}	7.26±1.04^{a}
Hot air drying	5.01±0.76^{b}	36.20±0.09^{b}	-3.16±0.02^{c}	3.87±0.08^{c}
Fresh	443.53±60.57^{a}	23.22±0.23^{c}	-1.55±0.10^{a}	4.22±0.26^{b}

*Mean value ± error (n=2). Different superscripts in same column are significantly different ($p \leq 0.05$).
L: lightness; a: chromaticity greenness/redness; b: chromaticity blueness/yellowness.

Table 2. Total antioxidant activity and total phenolic compounds of fresh Spirulina and dried samples from hot-air and microwave drying

Treatment	Total antioxidant DPPH ASSAY (mgGAE/100 g (DM))	Total antioxidant FRAP ASSAY (mgFeSO4/100g (DM))	Total phenolic compounds (mgGAE/100 g (DM))
Microwave	52.23±0.41^{b}	964.74±31.68^{b}	273.26±16.88^{b}
Hot air	21.00±0.01^{c}	516.64±44.66^{c}	99.76±3.64^{c}
Fresh	69.82±13.16^{a}	1585.35±45.96^{a}	371.43±39.32^{a}

*Mean value ± standard error (n=2). Different superscripts in same column are significantly different ($p \leq 0.05$).

The total antioxidant capacity and total phenolic compounds values of fresh Spirulina and dried Spirulina using both drying methods are shown in Table 2. The total antioxidant activity and total phenolic compounds values of dried samples and fresh sample differed significantly ($p \leq 0.05$). The Spirulina sample obtain form the microwave vacuum dryer showed the total antioxidant activity and total phenolic compounds content loss smaller than hot air dryer. The losses of total antioxidant capacity and total phenolic compounds during the drying operation with hot air dryer were more than approximately 50% when comparing the microwave dryer. Costa *et al.* [4] reported that the total antioxidant activity is related to the amount of total phenolic compounds present in Spirulina. Microwave heating is based on the transformation of alternating electromagnetic filed energy into thermal energy by affecting the polar molecules of a material. The material can absorb microwave energy directly and internally and convert it into heat [16]. Microwave heating led to the destruction of parenchyma cells in orange peel [17] and hot air

drying of orange peel around 50-60ºC apparently promote the minor disruption of cell wall polymers [18]. The intense heat generated from the microwaves creates a high vapor pressure and temperature inside plant tissue, resulting in the disruption of plant cell wall polymers. Consequently, antioxidant activity and total phenolic can be released, thus causing more antioxidant and total phenolic extracted.

3.3 Sensory descriptive analysis

Table 3 shows the final list of 16 sensory descriptive attributes and their definitions for Spirulina as agreed upon by all panelists: green-yellow color, particle size, four odors (fish, salty, seaweed, green), three tastes (salt, bitter, umami), three flavors (Chicken, fish, algae) and four aftertastes (oily, bitter, pork, astringent). Ten panelists determined the reference for evaluating the sensory attributes. Each panelist rated the attribute intensity of each reference. The mean intensity rating was calculated and used as the attribute intensity rating for that particular reference. References were used to remind panelists of particular sensory descriptors and help them to differentiate between descriptors [19].

Table 3. Attribute, definitions and intensity of dried Spirulinasensory characteristics.

Attribute	Definitions	References (Intensity)
Appearance		
Green-yellow	The color intensity of dried Spirulina from yellow to green	Munsell book 7.5 GY 2/4 (7.0)
Particle size	The dimensions of solid particles of dried Spirulina powder	Powdered sugar 5 g (2.1) Fine crystal sugar 3 g (6.4) Large crystal brown sugar 3 g (10.7)
Aroma		
Fish	Aroma asscociated with dried fish	Fresh *Spirulina platensis* 0.1 g (1.0) Fresh *Spirulina platensis* 1.0 g (5.1) Fresh *Spirulina platensis* 5.0 g (14.0)
Salt	Aroma asscociated with salt	Dried fish 0.3 g (3.0) Dried fish 1.0 g (7.7) Dried fish 3.0 g (14.0)
Seaweed	Aroma asscociated with seaweed	Fresh *Spirulina platensis* 0.1 g (0.5) Fresh *Spirulina platensis* 1.0 g (4.2) Fresh *Spirulina platensis* 5.0 g (8.0)
Green	Aroma asscociated with green vegetables	Dried lettuce 2.0 g (3.0) Dried Chinese broccoli 2.0 g (8.8) Dried spinach 2.0 g (13.5)

Table 3. Attribute, definitions and intensity of dried Spirulinasensory characteristics. (cont.)

Attribute	Definitions	References (Intensity)
Flavor		
Chicken	Aroma asscociated with cooked chicken perceived by smell perceived when the sample is inside the mouth.	Chicken soup 3.0% W/V (4.0) Chicken soup 10.0% W/V (7.6) Chicken soup 15.0% W/V (14.0)
Basic taste		
Salty	A fundamental taste factor associated with sodium chloride solution perceived by the tongue.	0.20% "Sodium solution" (2.5) 0.35% "Sodium solution" (5.0) 0.50% "Sodium solution" (7.5)
Umami	A fundamental taste factor associated with glutamate solution perceived by the tongue.	0.046% "Monosodium glutamate" (1.0) 0.350% "Monosodium glutamate" (7.5)
Bitter	A fundamental taste factor associated with caffeine solution perceived by the tongue.	0.01% "Caffeine solution" (2.0) 0.02% "Caffeine solution" (3.5) 0.035% "Caffeine solution" (5.0)
Fish	Aroma asscociated with dried fish perceived by smell perceived when the sample is inside the mouth.	Fish soup 3.0% W/V (3.5) Fish soup 10.0% W/V (7.3) Fish soup 15.0% W/V (12.5)
Seaweed	Aroma asscociated with seaweed perceived by smell perceived when the sample is inside the mouth.	Seaweed soup 0.5% W/V (2.5) Seaweed soup 2.5% W/V (7.6) Seaweed soup 3.5% W/V (14.0)
Pork	Aroma asscociated with cooked pork perceived by smell in mouth.	Pork soup 5.0% W/V (5.5) Pork soup 10.0% W/V (8.2) Pork soup 15.0% W/V (12.0)
Astringent	The shrinking or puckering of the tongue surface caused by alum after swallowing.	0.03% "Alum solution" (1.5) 0.05% "Alum solution" (2.5) 0.10% "Alum solution" (5.0)

*Rated on a 15-cm unstructured line scale with anchors at 1.5 and 13.5 cm.

Table 4. Intensity rating of dried Spirulina from hot air drying and microwave drying

Attribute	Drying assay	
	Hot air drying	Microwave vacuum drying
Appearance		
Green-yellow	8.32±0.93[a]	5.27±0.98[b]
Particlesize[ns]	3.20±0.33	3.41±0.32
Aroma		
Fish	5.83±0.77[b]	6.97±0.53[a]
Salt[ns]	2.28±0.57	2.28±0.39
Seaweed	8.10±0.51[a]	6.58±0.83[b]
Green[ns]	6.31±0.72	5.78±0.57
Basic Taste		
Salty[ns]	1.59±0.38	1.37±0.61
Umami[ns]	0.81±0.22	1.00±0.36
Bitter[ns]	1.96±0.38	1.48±0.37
Flavor		
Chicken[ns]	7.55±0.75	6.73±0.81
Fish[ns]	5.79±0.86	5.48±0.71
Seaweed[ns]	8.62±1.02	8.51±0.99
Aftertaste		
Oily[ns]	1.38±0.33	1.07±0.14
Bitter[ns]	1.29±0.36	1.35±0.27
Pork[ns]	6.71±0.64	6.30±0.57
Astringent[ns]	1.62±0.32	1.44±0.48

Mean value ± standard error (n=10). Different superscripts in same row are significantly different ($p \leq 0.05$).

The generic descriptive analysis results (Table 4.) differed significantly for 3 of the 16 attributes ($p \leq 0.05$) used todescribe the dried Spirulina samples (Table 3): color attribute, fishy odor, and seaweed odor ($p \leq 0.05$).Spirulina dried with hot air had more seaweed odor than Spirulina dried with microwave vacuum, but Spirulina dried with microwave vacuum had the lightest color and more fish odor than Spirulina dried with hot air. The results are presented in a spider diagram (Figure 1). Green-yellow color, fish aroma, and seaweed aroma were the only dried-Spirulina attributes that differed between the two drying methods.

4. Conclusions

The drying method affected on the color value L*, a*, and b*, total antioxidant activity, total phenolic compounds, color attribute, fishy odor, and seaweed odor of Spirulina samples. Microwave-vacuum drying retained more total antioxidant activity and total phenolic compounds than hot-air drying. Microwave-vacuum drying also produced a lighter color and stronger odor

than hot-air drying. The taste, flavor and aftertaste of both dried Spirulina samples did not differ significantly. The two different dying methods affected the physicochemical properties and sensory characteristics of *Spirulina platensis* differently.

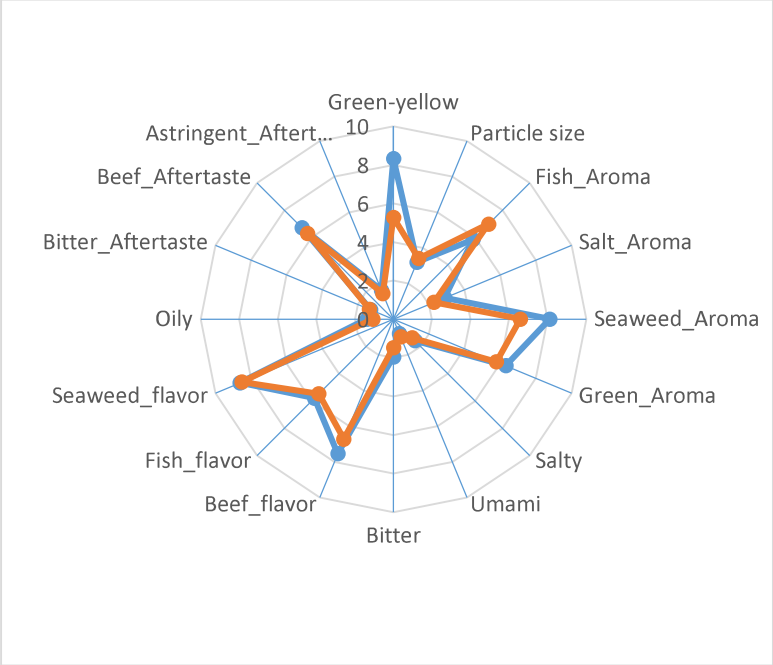

Figure 1. Sensory characteristics of dried *Spirulina platensis*

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