The Perception of Consumers Towards Microalgae as an Alternative Food Resource in Bangladesh: A Contingent Valuation Approach

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https://doi.org/10.5109/6781028

出版情報：Evergreen. 10 (1), pp.1-17, 2023-03. 九州大学グリーンテクノロジー研究教育センター
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The Perception of Consumers Towards Microalgae as an Alternative Food Resource in Bangladesh: A Contingent Valuation Approach

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(Received November 10, 2022; Revised January 18, 2023; accepted January 19, 2023).

Abstract: Faced with starvation and malnutrition, *Spirulina* may be considered an alternative potential food supplement in developing countries like Bangladesh. Building on the safety and broadly accepted use of algae as an alternative food resource in Bangladesh, this study aimed to evaluate the willingness to pay (WTP) for three kinds of algae food products: *Spirulina* tablet/capsule, *Spirulina* powder, and *Spirulina* supplement foods. A survey was conducted through online and in-person interviews among Bangladeshi adults by using contingent valuation (CV) method. The surveyor collected socio-demographic characteristics, knowledge, uses, acceptance, and attribute preference of *Spirulina* as a food supplement. Statistical tool ANOVA was executed to analyze and identify the influencing factors of *Spirulina* as a future food supplement. Among the 3000 respondents surveyed, 1533 (51.11%) stated that they would accept *Spirulina* as a food supplement, while others would accept *Spirulina* as a tablet/capsule (15.64%) and powder (33.43%), respectively. The average WTPs of *Spirulina* tablet/capsule, powder, and supplement are estimated to be US$ 4.18, US$ 3.66, and US$ 4.8, respectively. To introduce *Spirulina* food products in Bangladesh as a practical importance for the industrial production of algae-based food supplements, we present positive and welcoming public attitudes towards new food products that are safe, healthy, and affordable.

Keywords: contingent valuation method; food supplement; *Spirulina*; willingness to accept; willingness to pay

1. Introduction

In the last two decades, most people in Bangladesh have been exposed to health risks due to vitamin A, iron, and protein deficiencies. According to FAO, about 73% of people cannot afford a balanced diet in Bangladesh [1)]. People need alternative cost-effective food resources enriched with these nutrients. Marine food resources may give us many alternatives. Marine assets are promising immense opportunities in the context of the blue economy, bio-economy, and algae are specifically attractive as a source of an ample form of high-value compounds for numerous uses [2,3)]. The pharmaceuticals, biochemicals, high-value foods, wastewater treatment, and feed industries are vastly growing based on the potential algae cultivation [4–6)]. Microalgae have unique benefits over other crops due to the photoautotroph's characteristics, which means they can produce their food by using CO_2 and sunlight. Microalgae consume 1.83 kg of CO_2 for producing 1 kg of dry algal biomass [7)]. The microalgae culture method can be integrated with the industrial power plant flue gas in commercial production, subsidizing air pollution, CO_2 emission, and reducing the algae production cost [8)].

Blue-green algae, *Spirulina* is a reasonably feasible resource of the high content of proteins (approximately 80%), vitamins, essential amino acids, minerals, and several high-value products [9,10)]. *Spirulina*-based products are promoted and used in several countries, such as Japan, Germany, the USA, Italy, France, Canada, Chile, Mexico, Thailand, India, and so on [11)]. Notably, Hussain [12)] studied

Lebanon microalgae species for use as food or renewable energy, and Al-thawadi [13] explored the Kingdom of Bahrain's public awareness of algal consumption behavior. In Japan, the *Spirulina* product's domestic market size is 0.8 billion yen every year [14].

Spirulina has been extensively used for nutritional attributes as an alternative food supplement in the last three decades. *Spirulina* is the potential resource of fatty acids, amino acids, phytonutrients, antioxidants [15,16], phycobiliproteins, minerals, and vitamins [17–19]. Researchers have observed that it is effective against some severe viruses, including influenza, herpes, hepatitis C virus, cytomegalovirus, and HIV [20,21]. *Spirulina* has been effective in reducing cholesterol [22], blood glucose, body weight, increased lipase activity, and boosted iron during pregnancy and lactation [23]. It also increased phagocytic activity, antibody production, spleen cell proliferation, and IgA, but decreased serum histamine levels, allergy reaction levels, IgE, and tobacco-induced cancer [24]. Recently, Adhikari et al., Bhatt et al., and Pendaya et al. [25–27] showed that *Spirulina* sp. could assist as an effective antiviral against SARS-CoV-2. NASA (National Aeronautics and Space Administration), JAXA (Japan Aerospace Exploration Agency), and the ESA (European space agency) proposed *Spirulina* as an ideal food for astronauts [28].

Algae can produce bioactive compounds with prospective cosmetic manufacturing applications [29–31]. Nevertheless, some microalgae genus has been explored and used in mercantile applications [32,33], including *Dunaliella*, *Porphyridium*, *Chlorella*, *Botryococcous*, and *Arthrospira* [34,35]. Some microalgae species imbibe UV radiation and hinder melanin synthesis actions [36–38]. *Arthrospira* sp., *Chlorella* sp., and *Porphyra* species proteins and hydrolysates have an intense affinity with skin and hair [39], providing proper viscosity and moisture retention [40]. Cosmetics, including *Spirulina*, have shown gloss, moisturizing feeling, tissue generation, face make-up, lipstick [41], better sensorial property, and wrinkle reduction [42,43].

Costa and Jongen [44] and Barcellos et al. [45] described that the new food products failure rate exceeded 60% in food sector markets. The pioneering of food innovation and new foodstuffs fail due to the repugnance of consuming unfamiliar foods [46–48]. Bellavance et al. [49] reported a lower tolerance for functional foods among consumers with a high level of food neophobia. Henchion et al., and Siegrist et al. [50,51] illustrated that some strategies are considered to triumph food neophobia, for example, repeated exposure, social perception, increasing food quality, familiarity, and adequate communication. Grahl et al. [52] showed that *Spirulina* sp. with partly soy yield firm and fibrous commodities with a reasonable algae flavor that will provide a more sustainable food in the future. Djilali et al. [53] studied the food tablets that comprised a mixture of date and *Spirulina* powder. This tablet flavor is improved compared with the pure *Spirulina* tablets. It is used in various ways: (i) consumed by all category people, (ii) natural drug delivery carriers, and (iii) chew tablets for patients.

The contingent valuation (CV) method [54] is an analytical technique generally used to induce the individual's preferences for different usable products. This method comprises questionnaires to obtain the participants' willingness to pay (WTP) for some community commodities [55,56]. CV method generally draw data on the socio-economic features of the participants' such as income, education, age, sex, and manners about assessing a willingness to pay function that contains these features as possible explanatory parameters [57,58]. This is the first study to evaluate the publics' demand and accession considering algal food products and command a price to organize the probable introduction of food supplements in Bangladesh. For these purposes, we use the contingent valuation approach, a well-known method for evaluating participants' willingness to pay or willingness to accept [59].

The study explores Bangladesh consumers' attitudes toward different forms of *Spirulina* processed foods. Furthermore, this paper determines the knowledge about microalgae- health benefits such as high-level protein, reduction of cholesterol and glucose levels in the blood, vitamin availability, and the effects of carbon dioxide on the environment. This is a pioneering study in Bangladesh to explore consumer acceptance and perception towards utilizing algae as an alternative food supplement to the best of our knowledge. The aim of this study to assess the willingness to pay (WTP) values for different kinds of *Spirulina* products in Bangladesh to eradicate the food scarcity. This study will provide necessary and pertinent information to the government, the public, and the manufacturers for better planning, budgeting, cultivating methods, and evaluating the real situation for a future sustainable algae-based food market industry in Bangladesh.

2. Methodology

2.1 Study variable

Throughout the research, two crucial variables are employed to assess the future market and human acceptability of algae food products in Bangladesh. The variables are willingness to accept (WTA) and willingness to pay (WTP). A common WTA and/or WTP function for individual participants is described as WTA and/or $\mathrm{WTA} = f(A_i, S_i)$, where A_i denotes the quality or quantity of the attributes, Si denotes the pertinent socio-economic characteristics. If participants have known *Spirulina* products or algae, they answered "Yes" otherwise "No". This study's salient feature is WTP measured to understand and exhibit how people would recognize this algae product. The bidding technique was applied to obtain the hypothetical value rather than accurate WTP, comply with the contingent valuation method.

2.2 Study design

The lack of historical data and food neophobia is the main obstacle in studying Bangladesh's marketplace for microalgae-based nutrients and food products. To obtain the hypothetical space for future algae products, we accomplished the survey using a questionnaire on 3000 participants. We assumed three pre-assigned bidding prices for three modes of food products (*Spirulina* tablet/capsule, *Spirulina* powder, and food supplement form of *Spirulina*). Before starting a face-to-face interview, we operated an online-based pilot test (among 200 people) that contacted independently. Afterward, we developed the final questionnaire, bidding price, and effectiveness by making a group suggestion. The bidding process was investigated and adjusted for the weekly consumption price of *Spirulina* products. In this study, Dhaka and its surrounding areas are considered for collecting data. Dhaka is the capital city in Bangladesh. It is the most densely populated area in Bangladesh as well as the world. The different cities were also considered according to the aims of the study, such as Cumilla, Gazipur, Tangail, and Chattogram. Chattogram is the business hub in Bangladesh. For this study, we collected data from different areas due to their high population density and level of development.

2.3 Survey questionnaire

The survey was conducted through google drive using indirect (social media) and direct interviews (April 2019 to March 2020) that takes 18-20 minutes for each participant. The questionnaire consists of four sections: The first part comprises participant socio-economic demographic information (gender, age, level of education, etc.). The second part consists of general knowledge about algae, its uses, and advantages. General knowledge included if they heard about algae, and which form of algae they prefer, among other questions. The third section includes particular knowledge about algae (*Arthrospira platensis*). This section also demonstrates the various uses of *Spirulina*, such as supplement food, baked goods, and absorption of CO_2. The final section of the questionnaire asked about the consumption of *Spirulina*. In this section, the survey evaluated the willingness of consumers to buy food made from algae, and determine *Spirulina* consumption acceptance by offering three modes (*Spirulina* tablet/capsule, *Spirulina* powder, and supplement form of *Spirulina*). A total of 3000 people has been randomly interviewed (533 on social media such as Facebook, LinkedIn, and Gmail, and 2467 have been interviewed in person). The survey questionnaire was designed in both English and Bangla language.

2.4 CV method

This study assumed the contingent valuation (CV) technique to evaluate the WTP for algal food acceptance behavior in Bangladesh. This study permitted us to quantify the WTA and WTP amount for *Spirulina* products, i.e., *Spirulina* tablet/capsule, powder, and supplement products. The WTP question consists of two steps: a double bounded dichotomous format question, followed by an open-ended question. Participants were asked questions can be answered in Yes or No in the dichotomous part to know whether or not they will procure *Spirulina* products at given rates. If a participant answered in “Yes” at each bidding stage, the following upper price was asked for the next section. Suppose someone answered in “No” then the lower price was offered. In the end, an open question was asked for the highest WTP price for the *Spirulina* products. Figure 1 shows the bidding prices with the CV technique described by the dichotomous question and then pursued by an open question asking the maximum WTP for each product type.

2.5 Statistical analysis

A two-way analysis of variance (ANOVA) was applied to evaluate the characteristics of the participants, inferential and descriptive statistics. Where appropriate, these two types of statistics have been quantified as averages, percentages, and variances. The statistically significant differences were identified if the level of p-value was less than 5 percent ($p < 0.05$), 1 percent ($p < 0.01$), and 0.1 percent ($p < 0.001$). This research illustrates both parametric and non-parametric estimates of the WTA and the mean amount of WTP for *Spirulina*-based products. All statistical analyses were performed using MATLAB and MS-excel software.

3. Results and discussion

3.1 Demographic characteristics

The socio-demographic features are summarized in **Table 1**. Among all participants, the average age was 27.94 years. Approximately 78% of them were from 18-29 years. In this survey, two-thirds of the participants are male (62.33%). Previous study showed that Bangladeshi women did not show interest to participate in survey study due to socio-cultural environment, lack of awareness, patriarchy, and lack of education [60,61]. Around 76% of the respondents have completed a bachelor’s degree, 22.1% are college-level students, and the rest comprises those who have completed their secondary school or primary school, and had no institutional education at all. About 74.83% of participants stated that their family or friends had diseases like diabetes, heart diseases, high blood pressure, or other diseases.

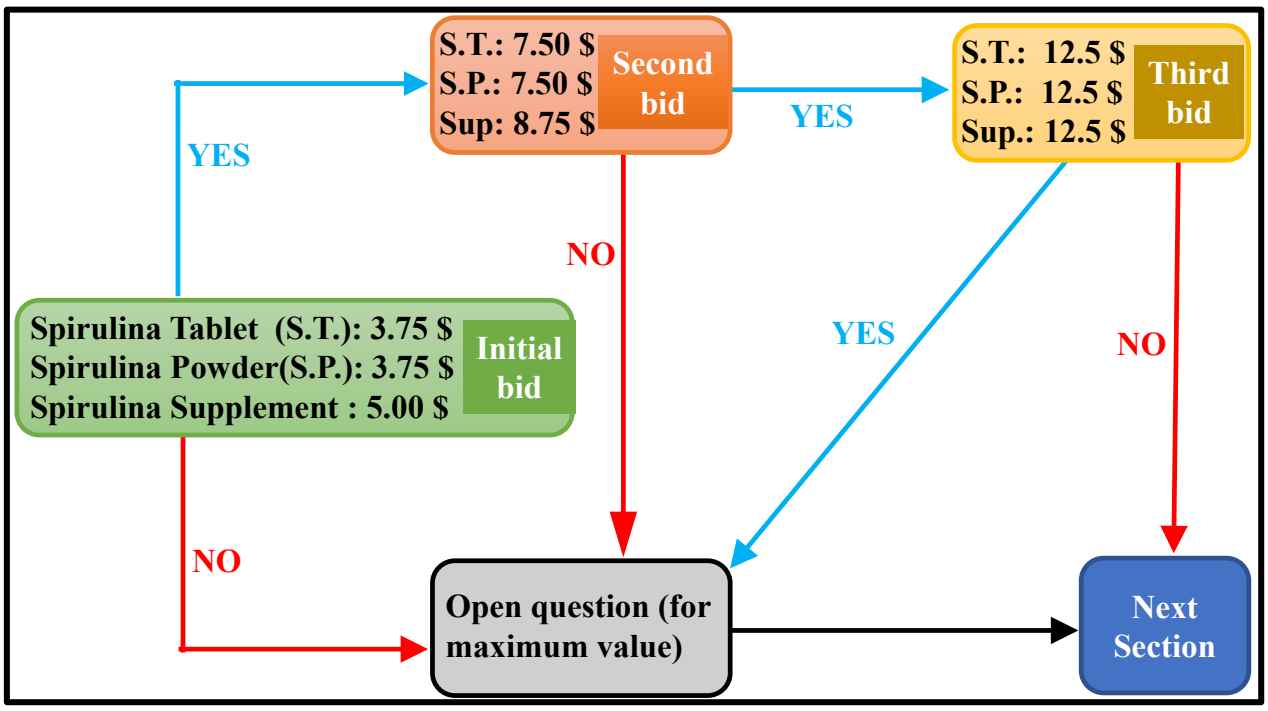

Fig. 1: Bidding game approach exhibited for elicitation of willingness to pay. Afterward, there was no earlier data on the price of *Spirulina* consumption in Bangladesh. The initial bid was (S.T. 3.75$, S.P. 3.75$ and Sup 5.0$) determined based on tests studied online and some previous studies.

Table 1. Participants socio-demographic outline for three kinds of *Spirulina* products

Variable		
Gender	**Number of participants**	**Percentages of participants**
Male	1870	62.33%
Female	1130	37.67%
Age		
18-29	2352	78.4%
30-39	457	15.23%
40-49	150	5%
50+	41	1.37%
Education		
Primary	31	1.03%
Secondary	18	0.6%
College	665	22.17%
Graduate	2286	76.2%
Profession		
Service (Govt./Private)	821	27.37%
Student	1905	63.5%
Farmer/Businessman	104	3.47%
Housewife/Unemployment	104	3.47%
Retired	66	2.2%
Income		
<250 US$	1149	38.3%

250-437.5 US$	670	22.33%
437.6-625 US$	529	17.63%
626-1250 US$	425	14.17%
>1250 US$	227	7.57%
Weight		
Overweight	1243	41.43%
Underweight	458	15.27%
Standard	1181	39.37%
Don't know	118	3.93%
Diseases exist		
Yes	2245	74.83%
No	755	25.17%
No information	1615	53.83%

Table 2. Participants algae and *Spirulina* knowledge with WTP for *Spirulina* products (Tablet/capsule, powder, supplement). ANOVA analysis (p-values) of various socio-demographic features of participants on WTP for *Spirulina* products. Numbers with ***, **, and * mentioned statistically significant level of 0.1%, 1%, and 5%, respectively.

Variable [(%)]		Average (Standard deviation)					P-values
	Tablet/Capsule		Powder		Supplement		
	Avg.	**S.D.**	**Avg.**	**S.D.**	**Avg.**	**S.D.**	
Knowing algae	**Do you ever know the name of algae or seaweeds?**						
Yes [2507 (83.57)]	4.13	3.84	3.66	4.31	4.89	4.83	Y/N=.488735 Food=0.034482*
No [350 (11.67)]	4.40	4.05	3.63	3.99	4.12	3.95	
Don't know [143 (4.77)]	4.45	3.62	3.66	3.51	5.02	3.32	
Knowing *Spirulina*	**Have you ever heard the name of *Spirulina*?**						
Yes [1385 (46.17)]	4.57	4.16	3.83	4.03	5.18	5.53	Y/N=0.028795* Food=0.005709**
No [1615 (53.83)]	3.90	3.68	3.51	4.67	4.45	4.06	
Don't know [291 (9.7)]	3.59	2.77	2.75	2.56	4.64	2.99	
Do you ever know the algae/seaweeds are very effective to resist the diseases?							
Yes [1468(48.93)]	4.34	4.13	3.82	4.70	4.93	5.28	Y/N=0.07228 Food=0.004951**
No [1081 (36.03)]	4.15	3.67	3.72	4.07	4.67	4.22	
Don't know [451 (15.03)]	3.75	3.26	2.94	2.66	4.70	3.55	
Have you ever heard about algae/seaweeds as an alternative food?							
Yes [1637 (54.57)]	4.21	3.85	3.74	4.57	4.94	3.92	Y/N=0.000424*** Food=0.000497***
No [1044 (34.8)]	4.38	3.97	3.75	4.06	4.90	6.01	
Don't know [319 (10.63)]	3.35	3.38	2.90	2.63	3.79	2.92	
Have you ever heard/seen algae/seaweed foods in the market/supermarkets?							
Yes [915 (30.5)	4.75	4.29	3.81	3.73	5.19	6.26	Y/N=0.251687 Food=0.086351
No [1755 (58.5)]	3.98	3.64	3.49	4.58	4.69	3.85	
Don't know [330 (11)]	3.70	3.47	4.10	3.54	4.35	3.43	

Table 3. Participants acceptance of alternative food characterized by WTP for three *Spirulina* products (Tablet/capsule, powder, supplement). ANOVA analysis (p-values) of various socio-demographic features of participants on WTP for *Spirulina* products. Numbers with ***, **, and * mentioned statistically significant level of 0.1%, 1%, and 5%, respectively.

Variable [(%)]		Average (Standard deviation)						P-values
		Tablet/Capsule		Powder		Supplement		
	Avg.	**S.D.**	**Avg.**	**S.D.**	**Avg.**	**S.D.**	
***Spirulina* has no cholesterol; will you be interested to take it as an alternative food?**							
Extremely interested [1656 (55.2)	4.50	4.16	3.92	4.65	5.46	5.42	Choice=0.010156* Food=0.005738**
Very interested [413 (13.77)]	3.76	3.16	2.97	2.45	3.64	2.84	
Interested [678 (22.6)]	3.82	3.16	3.46	3.88	4.17	3.13	
Neutral [73 (2.43)]	3.93	3.80	3.68	1.95	4.87	2.63	
Not interested [180 (6)]	3.63	4.86	3.54	5.17	3.81	5.36	
***Spirulina* stimulates the production of blood cells and enhances the immune system; will you take it as an alternative food?**							
Extremely interested [1866 (62.2)	4.40	3.94	3.97	4.63	5.17	4.01	Choice=0.327323 Food=0.071527
Very interested [313 (10.43)]	4.18	3.33	3.17	2.77	3.67	3.47	
Interested [611 (20.37)]	3.66	3.27	3.00	3.18	3.89	3.22	
Neutral [92 (3.07)]	3.95	3.44	3.31	2.32	4.22	2.65	
Not interested [118 (3.93)]	3.61	6.00	3.60	5.98	7.13	14.15	
***Spirulina* contains a very high amount of protein compares to other food sources; will you take it as an alternative food?**							
Extremely interested [1453 (48.43)	4.59	4.08	3.91	3.84	5.14	4.04	Choice=0.00038*** Food=0.000928***
Very interested [422 (14.07)]	3.65	2.86	2.86	2.10	3.43	2.47	
Interested [820 (27.33)]	3.80	3.20	3.58	5.10	4.89	6.03	
Neutral [128 (4.27)]	4.76	4.77	4.68	5.01	5.62	5.04	
Not interested [177 (5.9)]	3.43	5.33	3.06	5.58	4.33	5.60	
***Spirulina* consists of multi vitamins, minerals and fatty acids, which is effective for human health. Will you take it as an alternative food?**							
Extremely interested [1394 (46.47)]	4.73	4.30	4.23	5.34	5.31	5.73	Choice=0.001522** Food=0.0000952***
Very interested [324 (10.8)]	3.89	3.46	3.31	3.02	4.18	3.50	
Interested [950 (31.67)]	3.58	2.69	2.96	2.49	4.31	3.31	
Neutral [211 (7.03)]	4.38	5.33	3.65	3.85	5.25	4.11	
Not interested [121 (4.03)]	3.01	3.04	3.39	3.18	3.81	3.43	
***Spirulina* absorbs CO_2 for their growth. CO_2 is a great concern for the environment. *Spirulina* is ecologically friendly for us also. Do you think that it is the high time to produce more *Spirulina* in our country in coastal area/low land?**							
Extremely interested [2416 (80.53)]	4.25	3.78	3.69	4.30	4.79	3.88	Choice=0.00887** Food=0.010415**
Very interested [196 (6.53)]	4.14	4.58	3.48	4.61	6.07	11.02	
Interested [104 (3.47)]	3.37	3.10	3.13	2.59	3.59	2.84	
Neutral [222 (7.4)]	4.41	4.26	4.02	3.95	4.75	4.08	
Not interested [62 (2.07)]	2.20	3.14	2.51	3.30	3.71	3.60	
Variable [(%)]	Average (Standard deviation)						P-values
	Tablet/Capsule		Powder		Supplement		
	Avg.	**S.D.**	**Avg.**	**S.D.**	**Avg.**	**S.D.**	

If any bread is made from seaweed *Spirulina*, what would be your reaction to this new product?							
Very positive [761(25.37)	5.11	3.94	4.27	4.97	5.64	4.25	Choice=9.21E-05*** Food=0.01406*
Positive [1605 (53.5)]	4.00	3.88	3.62	4.66	4.56	3.67	
Neutral [551 (18.37)]	3.41	2.80	2.82	2.77	4.33	6.92	
Negative [32 (1.07)]	2.54	3.38	2.27	3.06	2.15	3.22	
Very negative [51 (1.7)]	5.23	7.44	5.22	7.82	6.85	7.32	
How interested would you buy food or baked goods which include a nutritional seaweed *Spirulina* product?							
Extremely interested [446 (14.87)]	5.37	4.54	4.85	4.21	6.25	4.57	Choice=0.00012*** Food=0.016112*
Very interested [425 (14.17)]	5.39	4.45	3.98	4.05	5.14	4.27	
Interested [1737 (57.9)]	3.89	3.35	3.49	4.25	4.71	4.85	
Slightly Interested [320 (10.67)]	2.73	2.76	2.51	3.13	3.13	2.93	
Not interested [72 (2.4)]	3.13	6.42	3.32	6.87	3.42	6.85	

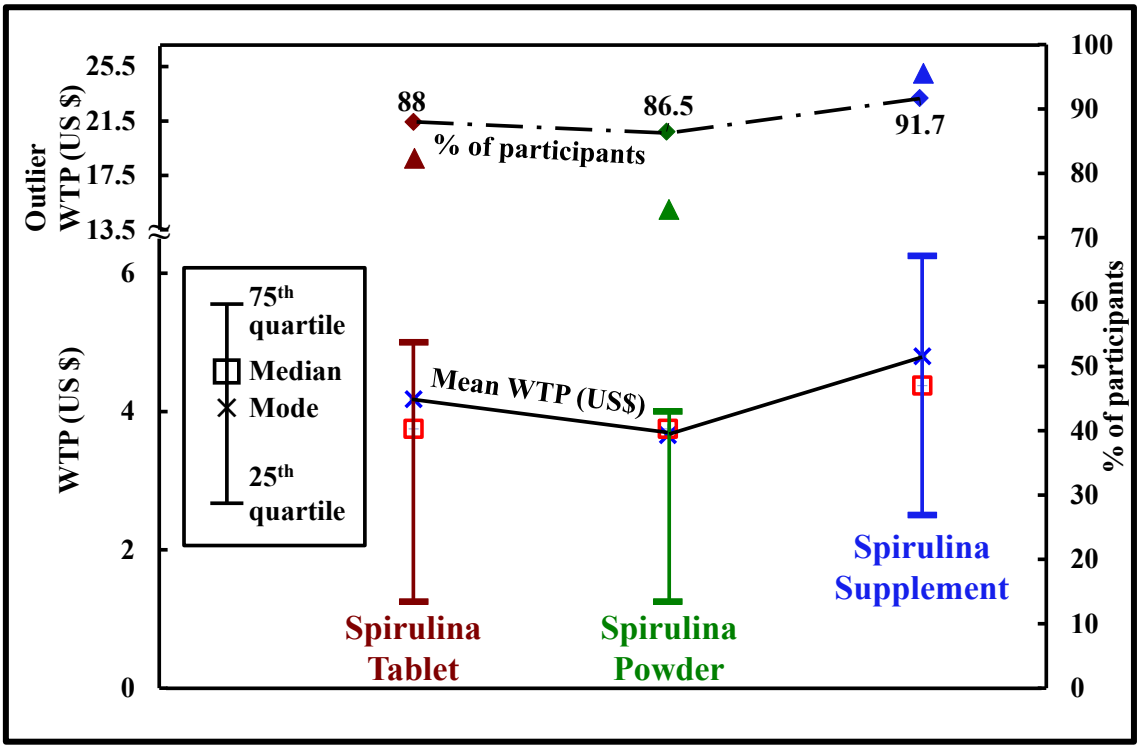

Fig. 2: Statistical outlines of participants mean WTA, WTP, and outlier WTP for *Spirulina platensis* products tablet, powder, and supplement food.

3.2 Willingness to accept and willingness to pay

Table 2 represents the participant's general knowledge about algae/algae products and specific algae named "*Spirulina platensis*." In **Table 2**, each question was asked either "No", "Yes" or "Maybe" as an answer for algae knowledge and availability of algae products in the market of Bangladesh. Almost 84% of participants were well known about algae/ seaweeds, whereas around 45% of respondents do not know about the specific algae, *Spirulina* sp. **Table 3** showed some questions about *Spirulina* consumption and uses by individuals with five-scale factors: extremely interested, very interested, interested, slightly interested, and interested. Approximately 60% of participants in Bangladesh are aware of their immune systems, blood pressure, and cholesterol. However, 50% of people are not aware of protein consumption, minerals, and fatty acid with their food. Nonetheless, most of the participants (approximately 81%) are interested in the environment and negative carbon emission issues. **Tables 1-3** shows the synopsis of statistical analysis for cross-relation demographic features of participants: age, income, service, education status, knowledge about algae, and health conditions, which affect the average willingness to pay of *Spirulina* products. There are some arrangements in this study where not only one but both of the two components

(highlighted by green) are assessed as more highly significant than 5%.

Fig. 2 illustrates the WTA outcomes for *Spirulina platensis*-based products with statistical data briefly. It also illustrates the statistical outline of willingness to pay among participants' socio-demographic features for three products with 25th percentile, mean, median, 75th percentile, and 95% confidence interval (CI). Participants' percentage who was firmly interested to use three modes of *Spirulina*-based products was 88%, 86.5%, and 91.7% for *Spirulina* tablets, powder, and food supplements respectively. In accordance with previous research, it can be said that people are influenced by several product attributes, including perceived edibility, healthiness, sustainability, and affordability [62]. In this regard, the outcomes attained here seem consistent. Moreover, in this survey, some responses deviant from the mass data are included in **Fig. 2**. Approximately one percent of data was identified as outliers. *Spirulina* supplement outlier WTP is almost double compared to *Spirulina* powder. **Fig. 2** summarizes data for three *Spirulina* products. The participants were more likely to buy *Spirulina* supplements, which means the WTP for *Spirulina* supplements was higher than other *Spirulina* products.

Based on the observed WTP for *Spirulina platensis* is shown in **Fig. 3**. It describes the distribution of different prices, agreeing on the bar diagram percentage. *Spirulina* powder is the most consumed product when the price is less than 6.25 US$. Nevertheless, it consumed the acceptance rate lower when the price is equal to or greater than 6.25 US$. In the survey, we found that participants with low income were interested in using *Spirulina* as a food supplement because of its food quality. In the earlier study, Grahl et. al.[52] found similar phenomena in the food consumption behavior of the people. Male participants were more likely to pay higher amounts for *Spirulina* products than women, as shown in **Fig. 4** (A). It is also observed in **Fig. 4** (B) that older people would like to pay more than young people for *Spirulina* products. Moreover, higher-income people and underweight people are more likely to pay more for all kinds of *Spirulina* products in **Fig. 4** (E).

Participants with general algae and blue-green *Spirulina* knowledge were correlated with the socio-demographic features. The percentage of knowing algae and *Spirulina* presented by participants' characteristics is shown in **Fig. 5**. The algae knowledge level was almost the same for all groups of ages and income group participants (**Fig. 5** (A)), but the level of algae knowledge increases with education levels. Nonetheless, participants' knowledge about algae had fluctuating tendencies with the profession. **Fig. 5** (B) illustrates the participants' specific knowledge about *Spirulina* algae and its products. In the case of *Spirulina* consumption attitude, all socio-demographic features have an increasing tendency such as higher income, age, and education level. This study observed that retired people are more interested in spending money on *Spirulina* consumption than other occupations. Eventually, it is clear from Figure 5 that participants with higher education, income, and age are more likely to have *Spirulina* algae knowledge. Lafarga et al. [63] showed that more than 52% of higher educated people know about microalgae-related food products in Spain whereas approximately 55% educated people in Bangladesh know about microalgae related products (Figure 5 A).

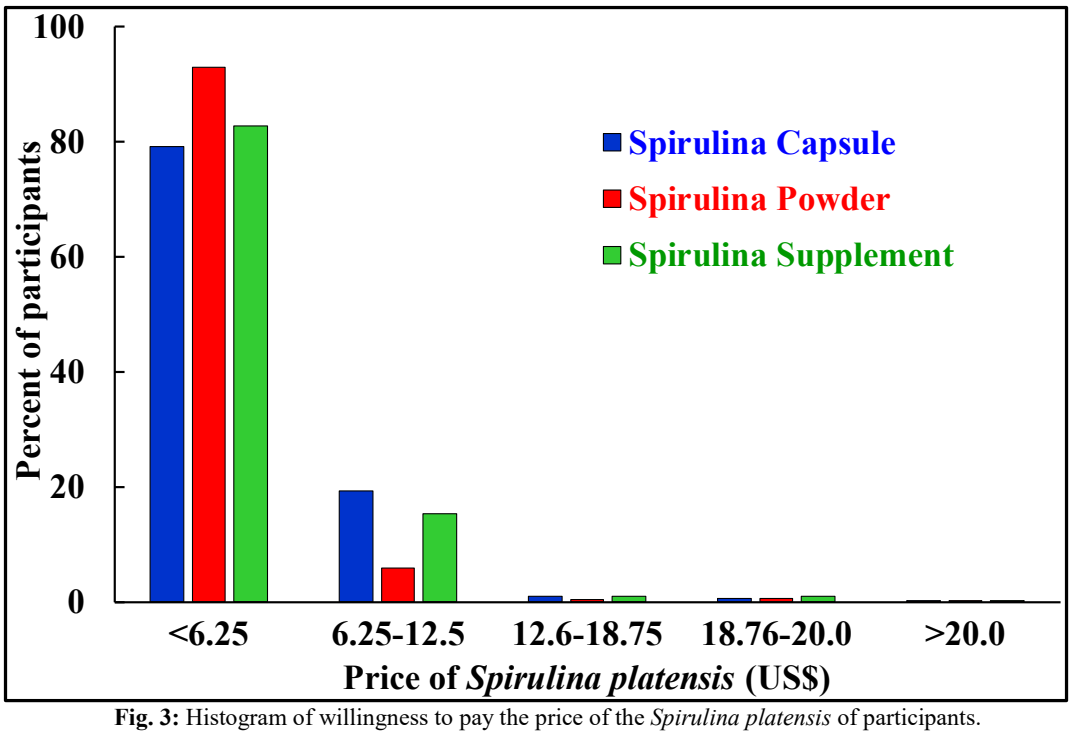

Fig. 3: Histogram of willingness to pay the price of the *Spirulina platensis* of participants.

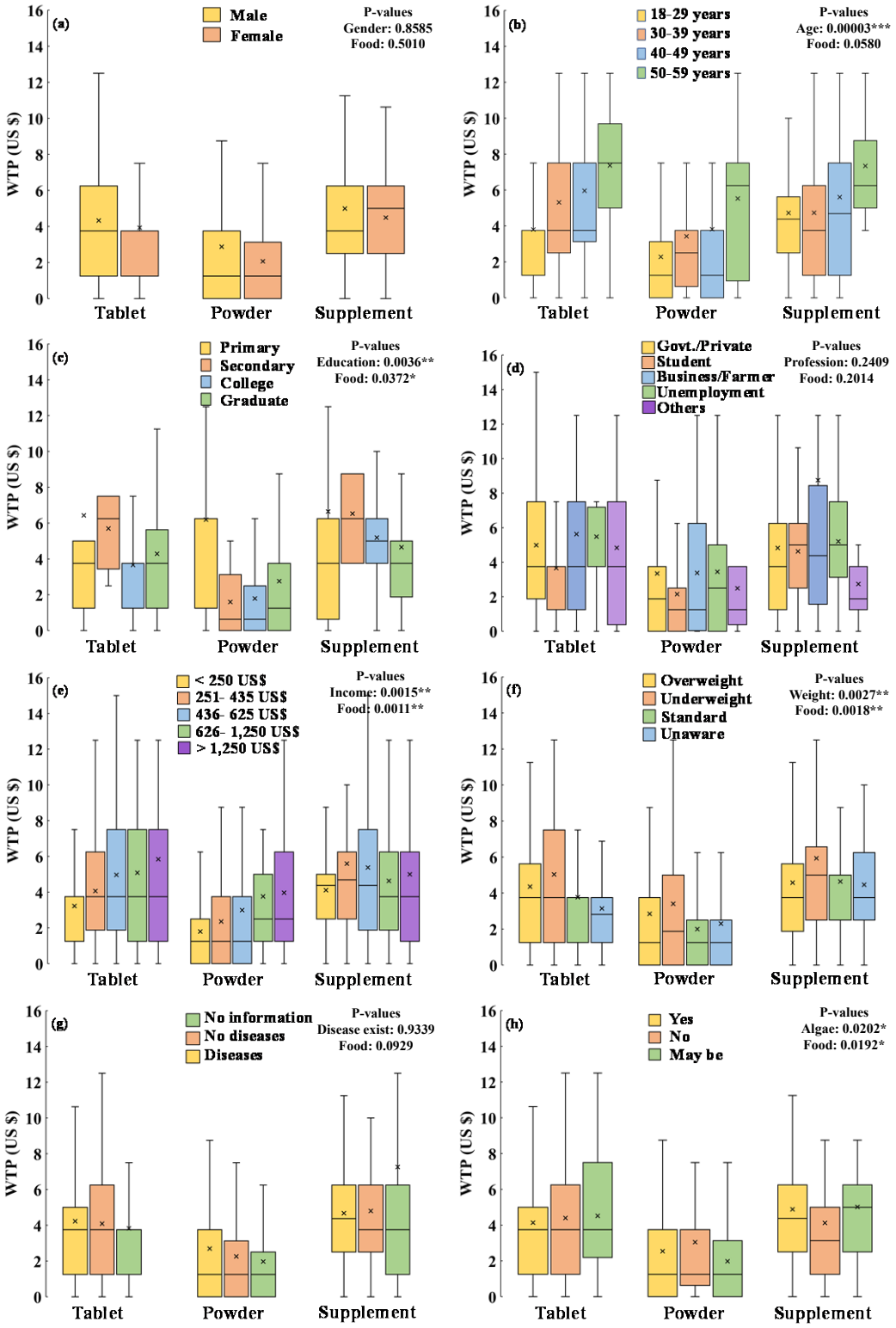

Fig. 4: Statistics of WTP of participants for different socio-demographic aspects: (a) gender, (b) age, (c) education, (d) occupation, (e) income, (f) weight, (g) existence of diseases, and (h) knowledge about *Spirulina* (cross (x) sign indicates mean, horizontal line indicates median, * indicates $p < .05$, ** indicates $p < .01$, *** indicates $p < .001$, and otherwise not significant).

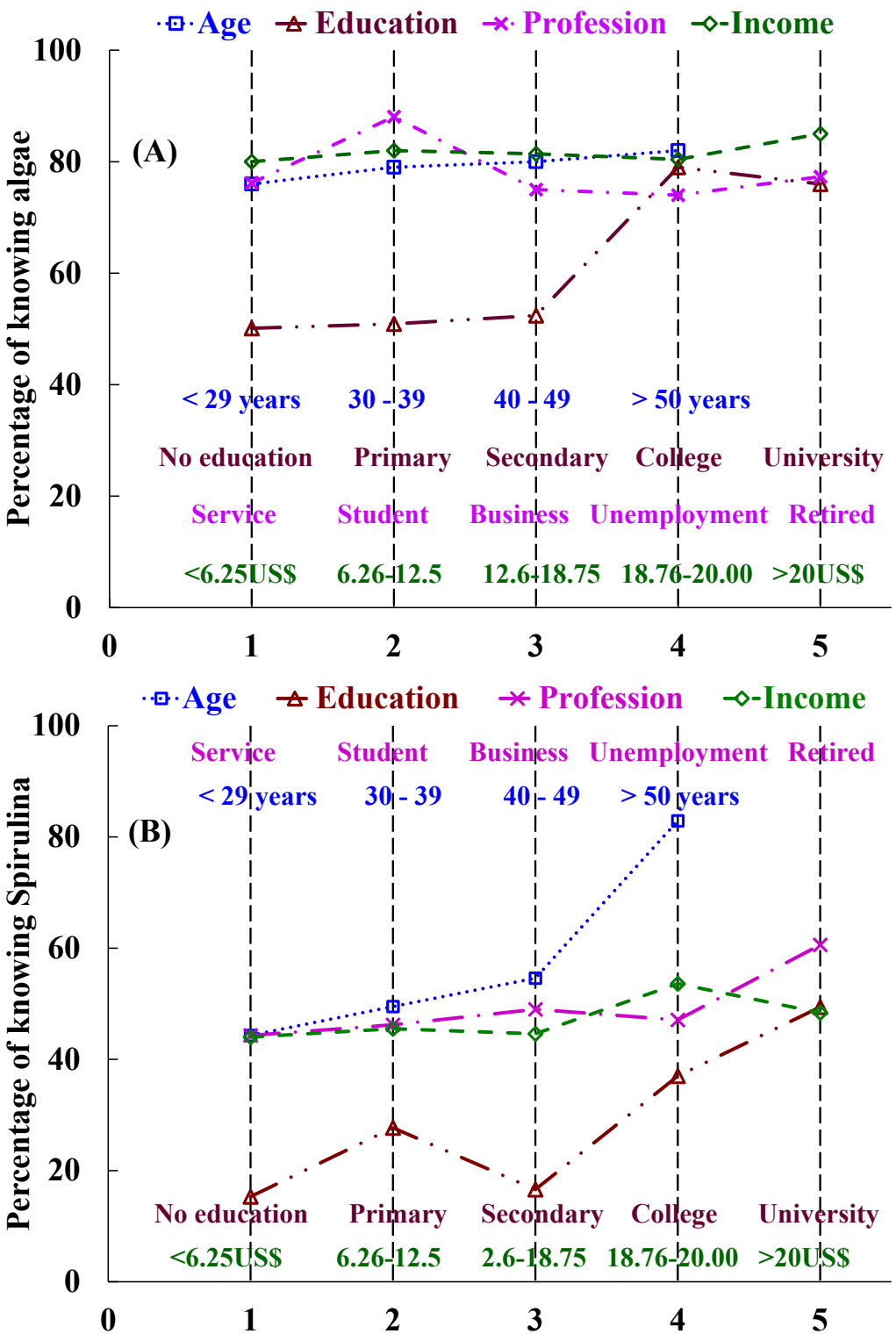

Fig. 5: Percentage of (A) general algae knowledge, and (B) knowledge about *Spirulina* by the participants' socio-demographic features: age, profession, education, and income.

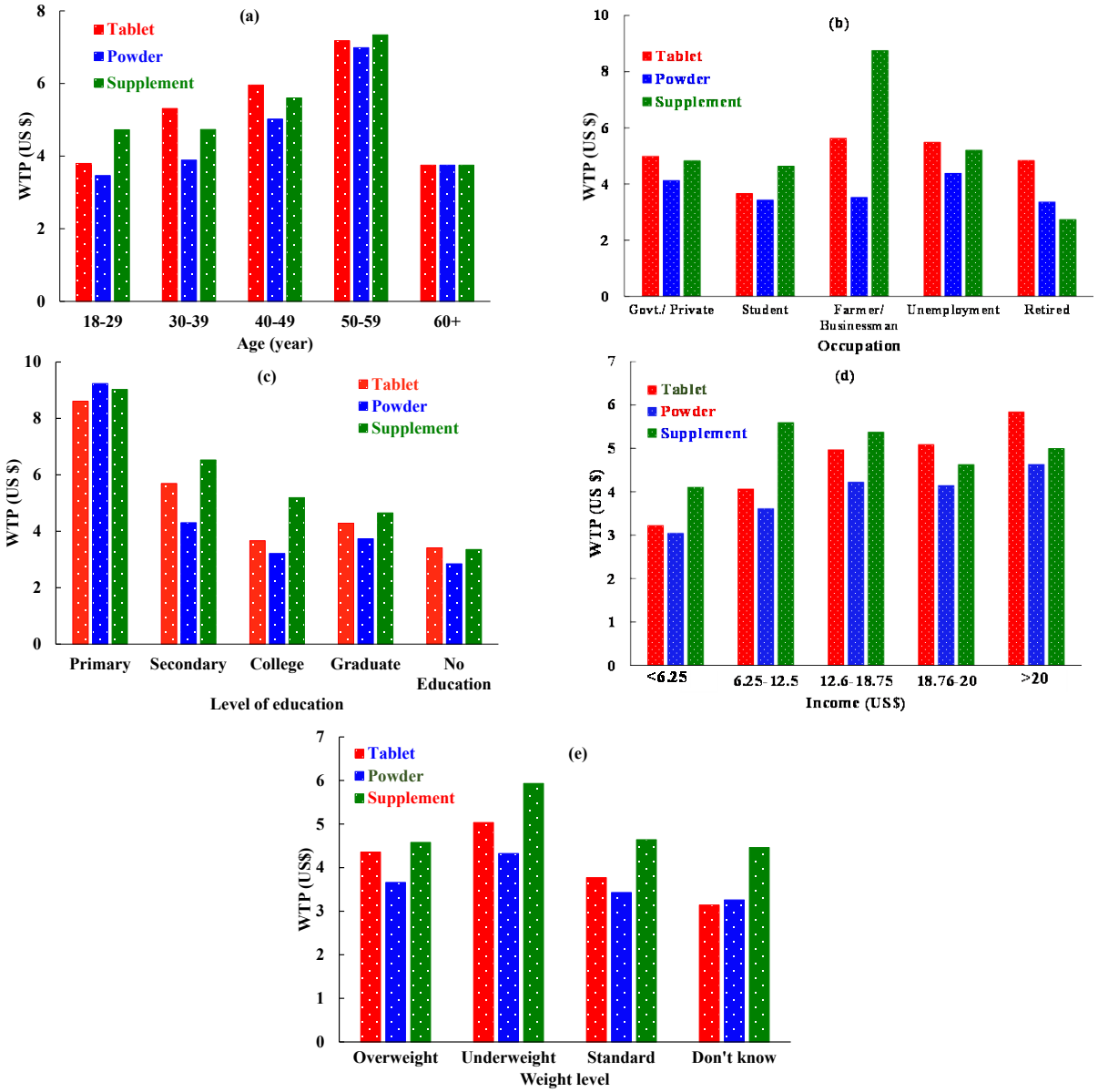

Fig. 6: Mean WTP amount for participants with five socio-demographic characteristics: (a) age, (b) occupation, (c) level of education, (d) income, and (e) weight.

The **Fig. 6** shows the two-dimensional bar charts of mean WTP corresponding to the age, income group, education, weight, and profession. According to the survey, older people accepted all types of *Spirulina* products more generally than younger ones, with the exception of those who are over 60 years. Older people have neophobia about new algae food products due to their culture and food habits. Earlier research found that older individuals are more averse to attempting new food products [64], though lessening with increasing income and education [65]. Retired people are more interested in buying tablets than other products. This study was observed that primary educated people offered more WTP than higher educated people. It may be because the primary educated people are included in the middle-aged (40-59) group people and are aware of the algal products. In this survey, it is also shown that WTP is increasing with the participants' higher income. The willingness to pay for any *Spirulina* products has been found to be the highest among the participants aged between 40 and 60 with relatively higher income.

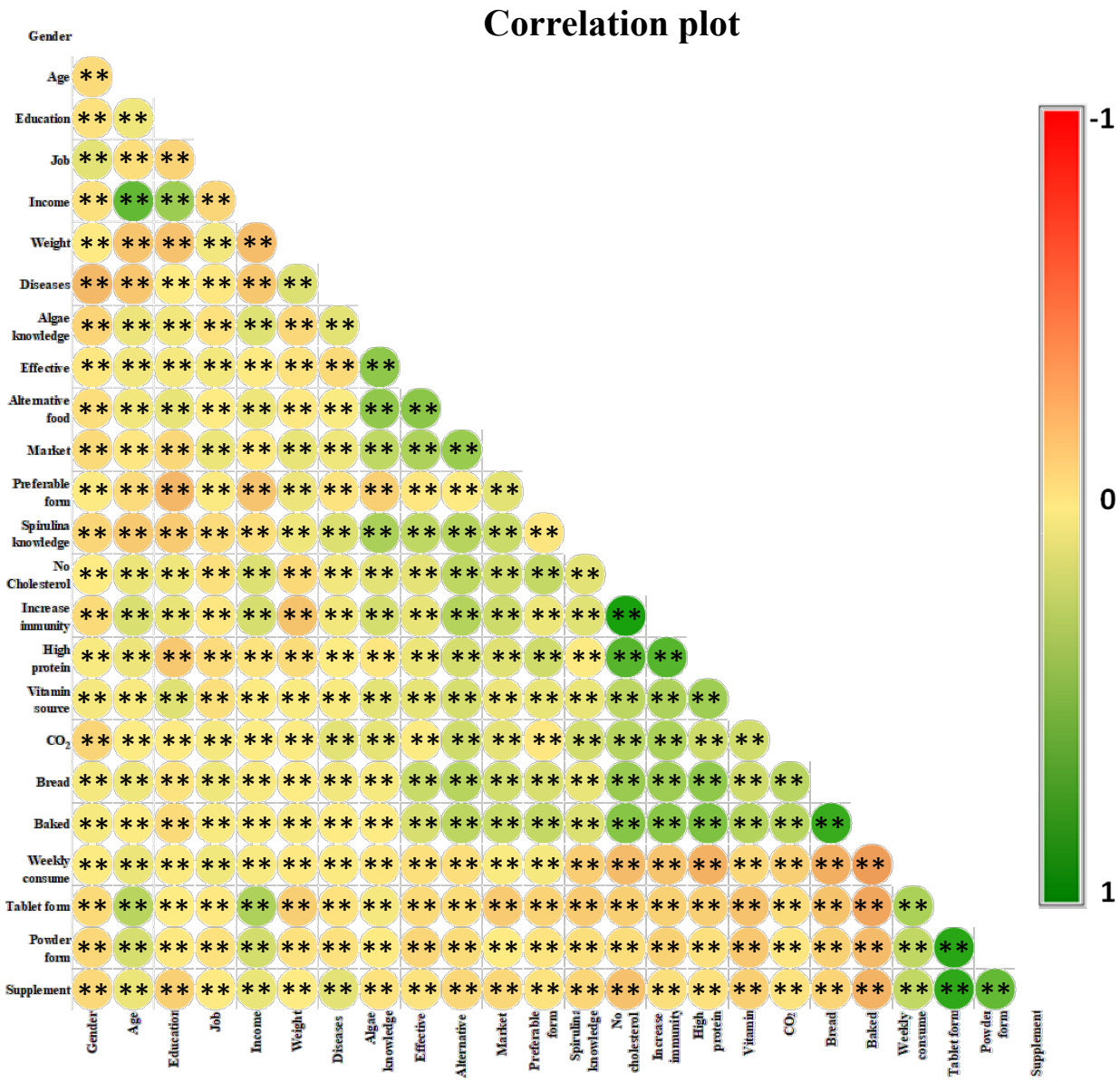

Fig. 7: Correlation matrix for algae as an alternative food consumption behavior and related other parameters (* indicates $p < .05$, ** indicates $p < .01$, and ns indicates not significant).

The correlation between two variables is quantified with a dimensionless number ranging from -1 to +1. The variables are inversely related if the value is negative. There is no correlation or relationship when the value is zero, and when the value is positive, they are directly related. From 0 to 1, the correlation strength increases, while from 0 to -1, the correlation strength decreases [66]. Age had a positive significant ($p < 0.01$) correlation with income and negative significant ($p < 0.01$) correlations with specific diseases such as diabetes, high blood pressure, heart disease, and constipation and *Spirulina* knowledge (**Fig. 7**). Algae-related product availability in the market and knowing algae were positively correlated with the consumption of algae as an alternative food. When people know that *Spirulina* has high protein, increases immunity, has no cholesterol, and uses CO_2 to produce food by photosynthesis then *Spirulina*-based bread and baked product are positively correlated (**Fig. 7**). However, baked and bread products had a negative correlation with *Spirulina* tablets, capsules, powders, and supplement products. The purpose of this paper is to explore why the customers consume microalgae and then to rate those reasons on a 5-point hedonic scale. The questions "(a) *Spirulina* reduces cholesterol level, (b) it has high protein, and (c) it enhances immune system" are significantly positive scored by the participants, with approximately 90%, 91%, and 93% respectively, of all responses (**Fig. 8**). Results revealed that *Spirulina* is considered a healthy option by most of the participants. Rutar et al. [10] showed that *Spirulina*-based food supplements would be reasonable when people choose a high protein, fatty acid, and amino acid content. Moreover, the statement "*Spirulina* absorbs CO_2 for their growth and environment friendly" is positively scored by the

consumers, approximately 91% for all responses. Microalgae's green appearance may have influenced consumers to view them as an environmentally friendly product because green is known to convince favorable environmental associations [67].

3.3 Consumer's attitude for *Spirulina* supplement products

According to the survey, the question "If any bread or baked products are made from *Spirulina*, what would be your reaction to this new product?" was given a positive score by the participants about 98% (**Fig. 8**). Except for very few publications [63,68], there are no studies on consumer acceptance and willingness to pay for *Spirulina* as food supplements or *Spirulina*-processed foods in Asian countries as well as in other countries. This study provides enough evidence for the potential flourishment of the algae-based food industry in Bangladesh. Although consumers are interested to consume algae-based food supplements, it is not available in the supermarket. Moreover, if the government takes the necessary steps for the development of algae-based farming then it will be possible to open a new era for the domestic food industry sector as well as international markets.

There may be some limitations in this research. First, women are probably less interested in participating in the survey than men due to the conservation nature of society. Second, this study did not survey food safety and efficacy. Third, this study is constrained to Bangladeshi customers. Besides, this study did not deliberate to test the validity of the time-to-think approach due to time, budget, and logistical restraints. Furthermore, selection bias could be associated with the sampling procedure.

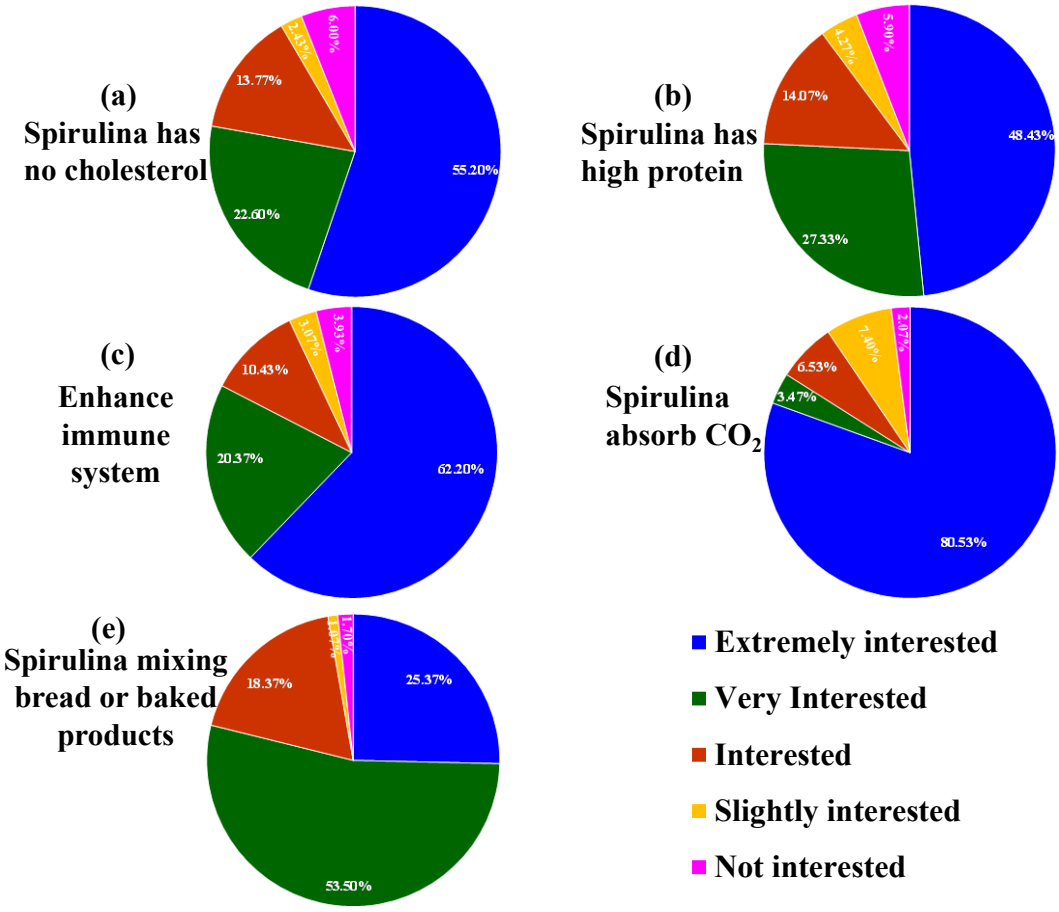

Fig. 8: Participants response to *Spirulina* related questions based on 5-point scale.

4. Conclusions

To the best of our knowledge, this survey is the first attempt to evaluate the willingness to pay for *Spirulina*-based alternative food consumption attitude in Bangladesh by the contingent valuation approach with the bidding game technique. This study estimates the respondents' preferences and the mean WTP value for *Spirulina* products. Statistical analyses recommend that higher WTP values are correlated with participants' income, education, other social characteristics, and knowledge about algae. Approximately 51% of the 3000 respondents responded that they would accept *Spirulina* as a food supplement, while others responded that they would accept it as a tablet/capsule (16%) or powder (33%). *Spirulina* tablet/capsule, powder, and supplement had average WTPs of US$ 4.18, US$ 3.66, and US$ 4.8, respectively. The most significant factors influencing awareness of *Spirulina* consumption were the education level and age group. The study findings may also have important policy implications for fulfilling consumer demand and WTP. Consumers in Bangladesh regard microalgae as organic, environmentally friendly, nutritious, and safe, all of which are important factors in commercializing a food ingredient. In the last decade, Bangladesh is one of the fast-growing economies around the world and is capable of maintaining GDP growth rates of over 6% except in the year 2020, and the country is currently seeing rapid urbanization, so the population moving to major cities is wealthier and able to buy healthier food products. Consequently, huge markets for healthy food products have been established, which may present advantageous chances for algae-based food industries. Thus, in the current attempt to find market opportunities in developing countries like Bangladesh, our findings illustrate the eating behavior of supplement products and huge business possibilities for manufacturers.

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