Sensory Acceptability of Iron-Fortified Red Lentil (*Lens culinaris* Medik.) Dal

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Abstract: Panelists in Saskatoon, Canada ($n = 45$) and Dhaka, Bangladesh ($n = 98$) participated in sensory evaluations of the sensory properties of both cooked and uncooked dehulled red lentil dal fortified with $FeSO_4{\cdot}7H_2O$, NaFeEDTA or $FeSO_4{\cdot}H_2O$ at fortificant Fe concentrations of 800, 1,600 (both cooked and uncooked), or 2,800 ppm. Appearance, odor, and overall acceptability of cooked and uncooked samples were rated using a 9-point hedonic scale (1 = dislike extremely to 9 = like extremely). Taste and texture were rated for the cooked samples prepared as typical south Asian lentil meals. Significant differences in sensory quality were observed among all uncooked and cooked samples at both locations. Overall, scores for all sensory attributes and acceptability of uncooked lentil decreased with increasing concentration of Fe in the fortificant; however, Fe fortification (particularly with NaFeEDTA) had small effects on acceptability. Panelists from Saskatoon provided a wider range of scores than those from Bangladesh for all attributes of cooked lentil. Overall, sensory evaluation of Fe fortification using NaFeEDTA minimally affected consumer perception of color, taste, texture, odor, and overall acceptability of cooked lentil. Reliability estimates (Cronbach's alpha [CA]) indicated that consumer scores were generally consistent for all attributes of all lentil samples (mean CA > 0.80). NaFeEDTA was found to be the most suitable Fe fortificant for lentil based on consumer acceptability. Consumption of 45 to 50 g of NaFeEDTA-fortified lentil (fortificant Fe concentration of 1,600 ppm) per day meets the estimated average requirements (EARs) of Fe for humans (10.8 to 29.4 mg).

Keywords: fortification, hedonic, iron, lentil, NaFeEDTA, sensory

Practical Application: Iron fortification of dehulled lentil dal may change organoleptic attributes that can influence consumer acceptability. Sensory evaluation by consumers helps to determine the effect on appearance, odor, taste, texture, and overall acceptability of fortified lentils. In this study, consumer acceptability was evaluated with panelists who consume lentil regularly. Panelists provided significantly different scores for 5 sensory attributes for 10 uncooked and 3 cooked lentil samples. Panelists reliably preferred NaFeEDTA as the most suitable Fe fortificant for dehulled lentils for 5 attributes. Overall, lentil dal fortified with NaFeEDTA can offer a simple and low-cost solution to human health problems associated with iron-related malnutrition.

Introduction

Interest in the consumption of low-calorie foods or vegetarian dishes is increasing throughout the world. This includes grain legumes (pulses), which play important roles in human health by providing energy, dietary fiber, protein, minerals, and vitamins (Gramatina, Zagorska, Straumite, & Svetlana, 2012). The 2 most widely consumed grain legumes, soybean and peanut, contain substantial amounts of edible oil. Most other grain legumes, including lentil (*Lens culinaris* Medik.), consist primarily of protein and carbohydrate, which includes dietary fiber (5.1% to 26.6%; Grusak, 2009). Global annual lentil production reached approximately 4.9 million tons in 2014 (FAOSTAT, 2017). Overall, about 56% of the lentil produced in the world is consumed in Asia (Kumar, Barpete, Kumar, Gupta, & Sarker, 2013), where it is considered a staple food. The consumption of lentil is increasing because it is fast cooking and an inexpensive source of protein compared to animal protein.

Improvement of the micronutrient content of staple crops, including lentil, is a means to mitigate Fe deficiency in the human diet. Several approaches have been explored to improve the Fe status of food crops, including fortification, biofortification, and genetic transformation. Fortification of foods with micronutrients and vitamins is considered one of the most effective ways to prevent human nutritional deficiencies (Bishai & Nalubola, 2002). Iron is an essential micronutrient in the human body, but more than 2 billion people, particularly in the developing world, are anemic, many due to Fe deficiency. Fortification of food with Fe has become a suitable and recommended approach to prevent and eradicate Fe deficiency (Mehansho, 2002). Food fortification is also mandatory now for various micronutrients and vitamins by legislation in 84 countries (Food Fortification Initiative, 2015). Fortification with Fe may cause organoleptic changes in food products, resulting, for example, in a metallic aftertaste, unacceptable flavor, undesirable color changes or degradation of vitamins (Mehansho, 2006). Sensory evaluation helps to determine the factors that affect the flavor of foods or drinks and their acceptability to the preferences

JFDS-2017-1183 Submitted 7/20/2017, Accepted 1/8/2018. *Authors Podder, Tar'an, and Vandenberg are with Dept. of Plant Sciences, Univ. of Saskatchewan, Saskatchewan, Canada. Author Khan is with James P. Grant School of Public Health, BRAC Univ., Dhaka-1212, Bangladesh. Authors Tyler and Shand are with Dept. of Food and Bioproduct Sciences, Univ. of Saskatchewan, Saskatchewan, Canada. Author Henry is with College of Pharmacy and Nutrition, Univ. of Saskatchewan, Saskatchewan, Canada. Author Jalal is with Nutrition Intl., Ottawa, Canada. Direct inquiries to author Vandenberg (E-mail: bert.vandenberg@usask.ca).*

doi: 10.1111/1750-3841.14066

Journal of Food Science A Publication of the Institute of Food Technologists

Figure 1–Images of the uncooked lentil samples, including the unfortified control (left-most column) and samples fortified with $FeSO_4 \cdot 7H_2O$ (top row), NaFeEDTA (middle row), and $FeSO_4 \cdot H_2O$ (bottom row) at fortificant Fe concentrations of 800, 1,600, and 2,800 ppm.

of consumers (de Melo, Bolini, & Efraim, 2009) and has become important as a means of assessing market acceptability. A series of techniques are used to measure the human response to foods and reduce the bias effects of brand identity and other information that may impact stakeholder perception (Lawless & Heymann, 2010). The Institute of Food Technologists and the American Society for Testing and Materials define sensory evaluation as a scientific method used to evoke, measure, analyze, and interpret responses to products as perceived through sight, smell, touch, taste, and sound (Stone & Sidel, 2004).

The aim of this study was to investigate the sensory properties of both uncooked and cooked, Fe-fortified, dehulled red lentil (dal) as determined by panelists that were familiar with lentil-based meals. The goal was to use this information to select the most appropriate Fe fortificant from the consumer point of view. In our previous Fe-fortification study, dehulled red lentil (dal) was fortified with 3 different Fe-fortificants ($FeSO_4 \cdot 7H_2O$, NaFeEDTA, and $FeSO_4 \cdot H_2O$) using 3 different fortificant Fe concentrations (Podder et al., 2017). After a series of experiments we identified an appropriate method and optimal dosages for Fe fortification of lentil. Fortified red lentil samples have a distinguishable appearance compared to unfortified lentil. Any change in the organoleptic properties of fortified lentil can be evaluated by consumers, and their remarks can provide valuable information to guide food scientists or product developers with respect to commercial food production. The key sensory attributes in this context are appearance, taste, odor, texture, and overall acceptability. To the best of our knowledge, this is the first report of a sensory evaluation by panelists of Fe-fortified lentil. In this study, uncooked and cooked samples were evaluated by lentil consumers in 2 locations, in Saskatoon, Canada (with panelists originally from 5 South Asian countries) and in Dhaka, Bangladesh (local panelists). Preferences in both locations were compared to determine if the groups had different sensory perceptions.

Materials and Methods

Ethical review

The study was approved by the Research Ethics Office, Univ. of Saskatchewan, Canada (certificate number, BH 14–320) and by the Ethical Review Committee of the James P. Grant School of Public Health, BRAC Univ., Bangladesh (ethics approval reference number 56).

Preparation of uncooked and cooked lentil samples

Commercial red lentil dal in the unsplit form (known as football type) was fortified with 3 different fortificants ($FeSO_4 \cdot 7H_2O$, NaFeEDTA, and $FeSO_4 \cdot H_2O$), each at 3 different fortificant Fe concentrations (800, 1,600, and 2,800 ppm). This resulted in a total of 9 uncooked fortified lentil samples plus an unfortified control sample (Figure 1). The fortification procedure was reported in our previous article (Podder et al., 2017), which provides details on choice of suitable fortificants, appropriate methods for lentil fortification, colorimetric study results of Fe-fortified lentil, assessment of proper dose of Fe fortificant, fortification duration, shelf-life, and boiling time of fortified lentil, as well as the Fe bioavailability and phytic acid concentration of Fe-fortified lentil. It also showed that 50 g of Fe-fortified lentil dal fortified with a NaFeEDTA solution containing 1,600 ppm of Fe could provide approximately 11 to 12 mg of Fe, including the intrinsic Fe present in the unfortified lentil and Fe added from the fortificant. This amount of Fe can meet the WHO and FAO's recommendation of 29.4 and 10.8 mg/Fe day for females and males, respectively, considering 10% bioavailability (WHO & FAO, 2006).

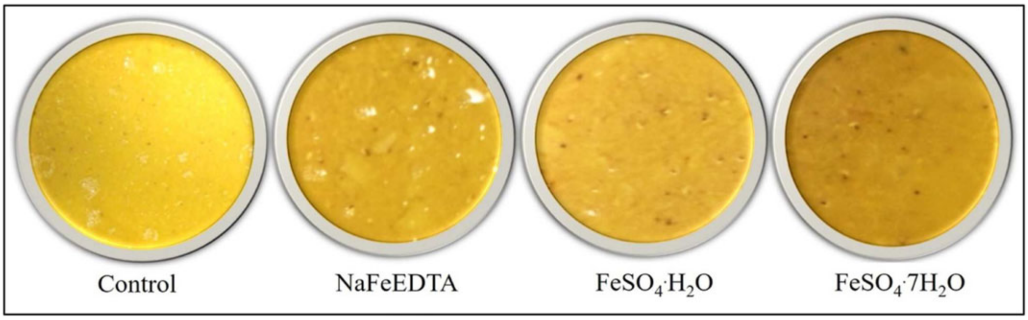

Figure 2–Four cooked dal samples including the control (left) and samples prepared using each of the 3 fortificants ($FeSO_4 \cdot 7H_2O$, $FeSO_4 \cdot H_2O$ and NaFeEDTA) at a fortificant Fe concentration of 1,600 ppm.

For sensory evaluation of cooked lentil, sub-samples of the unfortified lentil and of lentil treated with each fortificant at a concentration of 1,600 ppm Fe were used to prepare a typical South Asian lentil dish (Figure 2). The recipe (Kohinoor et al., 2010) used to prepare the dish involved cooking 500 g of each of the 4 lentil samples (unwashed) for 25 min in 2.5 L of deionized water. The result was a semi-thick soup, a south Asian traditional lentil dish to which 20 g of table salt, 10 g of turmeric powder, 30 mL of canola oil and 100 g of chopped onion were added for the last 5 min of cooking. Food samples were prepared in the food sensory laboratory of the Univ. of Saskatchewan and the Food Processing Laboratory of icddr,b (Intl. Centre for Diarrhoeal Disease Research, Bangladesh) in Dhaka, Bangladesh. Samples were allowed to cool to room temperature and then portioned in cups with lids. Four cooked samples were served at room temperature in a single tray.

Selection of panelists

The sensory evaluation was performed in 2 locations. In Canada, 45 untrained panelists (aged 18 to 57 years) were recruited from staff and students at the Univ. of Saskatchewan. All panelists were originally from South Asia, specifically Bangladesh (18), India (15), Nepal (5), Sri Lanka (5), and Pakistan (2). This region has a long tradition of lentil consumption in a form similar to that used in this study. The sensory evaluation was conducted twice with these participants. In Bangladesh, 101 untrained panelists (aged 18 to 60 years) were recruited, all of whom lived in Dhaka, Bangladesh and were employed at the James P. Grant School of Public Health (JPGSPH), BRAC Univ.

Consent (verbal and written) was obtained from all participants. Participants were excluded if they were less than 18 or over 60 years of age or if they were suffering from a cold, fever, or gum inflammation. Other exclusion criteria included those taking medicines for treatment of cancer or thyroid, neurologic, or psychiatric ailments. Anyone with an allergy to lentil, with Fe deficiency or who was pregnant was excluded due to potentially altered taste perception. In Bangladesh, panelists who had used *Paan/Jarda* (a preparation combining betel leaf with betel nut and tobacco) within one hr of the sensory evaluation were excluded due to potential residual psychoactive effects.

Sensory evaluation and data collection

In Saskatoon, participant consent and sensory evaluation forms were provided to all participants to start the evaluation. The consent form described the purpose of the sensory evaluation studies, food preparation procedures, potential risks of evaluation, confidentiality of each participant's evaluation, and procedures should a participant choose to withdraw from the evaluation. In Bangladesh, the data collection procedure was similar, except that another structured questionnaire was supplied to the evaluators to collect data on socio-economic indicators such as monthly income, education, and household status. In both locations, lentil consumption frequency, purchasing frequency, and place of purchase were recorded when possible to assist in determining the lentil consumption pattern among panelists. The sensory evaluation form comprised 3 parts. First, some general information on participants was recorded as coded information, including participant, age, sex, date, and sample code. The second part comprised questions using a 9-point hedonic scale (1 = dislike extremely to 9 = like extremely) to describe the appearance, odor, and overall acceptability of the uncooked samples, and the appearance, odor, taste, texture, and overall acceptability of the cooked lentil samples. In the third part, any additional opinions of participants were documented (verbatim), whether positive or negative. Participants were requested to carefully read and then sign the consent form prior to starting their evaluation. For the Bangladesh location, all forms and questionnaires were translated into Bangla (the most commonly spoken language). This ensured that the meaning of questions was not altered; back-translation to English also was performed by the investigators. Furthermore, data in Bangladesh were collected by 11 research assistants in face-to-face interviews (as opposed to participants filling out their own forms in Saskatoon).

In Saskatoon, data collection was completed in a single day (9:30 a.m. to 3:30 p.m.) for each replication in 7 individual booths at the Univ. of Saskatchewan Food Sensory Laboratory. All booths were well illuminated with white light and separated from each other to avoid any communication among participants. In Bangladesh, sensory evaluation also was completed in a single day (9:30 a.m. to 2:30 p.m.). A total of 11 partitioned booths were constructed for data collection and all tests were performed under uniform white light conditions. The study investigators were present for the purpose of overall supervision and monitoring. In both locations, participants received cooked lentil dal prepared from approximately 17 g of uncooked lentil from each of the 4 lentil samples. If they consumed all 4 samples, participants would have ingested a total of 11.40 mg of Fe (10.25 mg from the total of the 3 fortified samples + 1.15 mg from the unfortified check). The tolerable upper intake level of iron per day for adults (19+ year) is 45 mg/d (U. S. Dept. of Health and Human Services, 2016), and thus we did not expect any side effects; moreover, the added fortificants were of food grade and have been approved by the FAO.

Sensory evaluation was conducted in single sessions to avoid reporting bias. Uncooked lentil samples (50 g) were presented in white plastic containers labeled with 3-digit codes. All of the uncooked samples ($n = 10$) were displayed on a single tray, all at once and in random order. All uncooked samples (including the control) were assessed visually because this is the form of lentil presented to panelists in the markets or supermarkets where purchase decisions are made. Cooked lentil samples (approximately 75 mL; $n = 4$) also were presented in random order in white plastic containers labeled with 3-digit codes. Water was provided to allow participants to conduct oral rinsing before and after testing each of the dishes.

Panelists' consistency assessment for sensory data based on the Cronbach's alpha coefficient

Cronbach's alpha (CA) has proven to be the best approach for assessing the internal consistency reliability (ICR) of a sensory panel (Pinto, Fogliatto, & Qannari, 2014). Its use is important for statistical expression of a panel's consistency and reliability in multi-item evaluation scores. CA is a numeric expression ranging between 0 and 1 (Tavakol, Mohagheghi, & Dennick, 2008) with the resulting CA value considered an index of reliability (Tavakol & Dennick, 2011). Reliability estimates measure the index of measurement error by squaring the correlations (α-values) and subtracting them from 1.00 (Kline, 1994). The value after subtraction shows the error variance in the score. We assessed the ICR of the sensory scores from 45 and 98 panelists in Saskatoon and Bangladesh, respectively, for the 10 uncooked and 4 cooked samples. An acceptable CA value range, as reported in a variety of studies (Bland & Altman, 1997; DeVellis, 2003), is 0.70 to 0.95.

Data analysis

The data from the 2 repeats from Saskatoon were combined and mean data were used in the analysis. Among the 101 panelists in Bangladesh, 3 did not complete the sensory evaluation form and their data were excluded from the analysis. Statistical analysis of the sensory data was conducted using SAS version 9.4 (SAS Inst. Inc., Cary, N.C., U.S.A.). For the questions regarding sensory attributes (appearance, odor, taste, and texture) and overall acceptability, 1-way analysis of variance (ANOVA) was used to verify the differences between the samples (including the control). The least significant difference (LSD) was calculated and the level of significance set at $P < 0.05$. The CA was analyzed using IBM SPSS version 24 (IBM Statistics, Version 24, 2016). Data were analyzed separately for the 2 sites due to different panel sizes.

Results

Consumer demographics from Bangladesh and Saskatoon

Demographic data for the study participants are shown in Table 1. The mean ages of the panelists in Saskatoon and Bangladesh were 35 years (range 18 to 57) and 30 years (range 19 to 49), respectively. Approximately 40% (Saskatoon) and 66% (Bangladesh) of the participants were in the 25 to 34-year age group. Nearly half (46%) of the Bangladesh participants had a monthly income of 30,000 to 39,000 Bangladesh taka (BDT; approximately 500 to 650 CAD). In Bangladesh, 28.7% of panelists had post-graduate degrees, and 10.9% had completed an undergraduate degree. Half (49.5%) of the panelists from Bangladesh had completed technical degrees (Master of Public Health, Master of Development Studies, MBA, Calif., and so on) after completing their undergraduate degrees. The remaining 10.9% of panelists had completed secondary or elementary school. Saskatoon panelists in the study had annual incomes ranging from 21,000 to 45,000 CAD and all had completed at least an undergraduate degree.

Table 1–Panelist demographics for Bangladesh and Saskatoon study sites.

Background characteristics		Saskatoon number (%)	Bangladesh number (%)
Gender	Male	28 (62.2)	53 (54.1)
	Female	17 (37.8)	45 (45.9)
Age (in years)	18 to 24	7 (15.6)	12 (12.2)
	25 to 34	18 (40.0)	65 (66.3)
	35 to 44	10 (22.2)	16 (16.4)
	45+	10 (22.2)	5 (5.1)
Panelist's attitudes toward lentil consumption			
Observation	Consumer responses	Number (%)	Number (%)
How frequently do you eat lentil?	Every day	5 (11.0)	18 (18.4)
	Every week	27 (60.0)	55 (56.1)
	Every month	13 (29.0)	25 (25.5)
How frequently do you buy lentil?	Every week	9 (20.0)	6 (6.1)
	Every month	30 (66.7)	63 (64.3)
	Do not buy	6 (13.3)	29 (29.6)
From where do you buy lentil?	Local market	–	37 (37.8)
	Grocery store	45 (100.0)	16 (16.3)
	Both sources	–	16 (16.3)
	Do not buy	–	29 (29.6)

Consumer attitudes toward lentil consumption

In both Saskatoon and Bangladesh, the majority of participants consumed lentil at least weekly (Table 1). The most common frequency of lentil purchase was monthly (63.3% and 66.7% of respondents in Bangladesh and Saskatoon, respectively). In Bangladesh, 37.6% of panelists bought lentil at local markets (where lentil is usually sold by scooping from open sacks), 13.9% at grocery stores (where lentil is usually sold in small packets of various sizes), and 15.8% at both. In Saskatoon, all panelists bought lentil from supermarkets. Approximately one-third of the Bangladesh panelists did not buy lentil, but were regular consumers, and ate lentil prepared by someone else (in homes or restaurants).

Sensory responses to the attributes of uncooked fortified lentil dal

Sensory scores obtained from panelists in both Saskatoon and Bangladesh for the ten uncooked samples are shown in Figure 3, along with their range, dispersion, and outliers. Consumer responses varied significantly for all three attributes (appearance, odor and overall acceptability) scored in both locations. For all attributes, the highest score was observed for unfortified control lentil samples, followed by NaFeEDTA-fortified samples at 800 ppm Fe, except in Bangladesh where NaFeEDTA-fortified lentil with 2,800 ppm Fe received the highest score, but this score was not significantly different from that of NaFeEDTA-fortified lentil at 800 ppm Fe. The lowest scores were obtained for the $FeSO_4{\cdot}7H_2O$- and $FeSO_4{\cdot}H_2O$-fortified samples at 2,800 ppm Fe at Saskatoon and Bangladesh, respectively. In both locations, the NaFeEDTA-fortified sample at the highest dose (2,800 ppm Fe) scored similarly to or higher than the $FeSO_4{\cdot}7H_2O$- and $FeSO_4{\cdot}H_2O$-fortified samples fortified with the lowest Fe dose (800 ppm) for all 3 attributes.

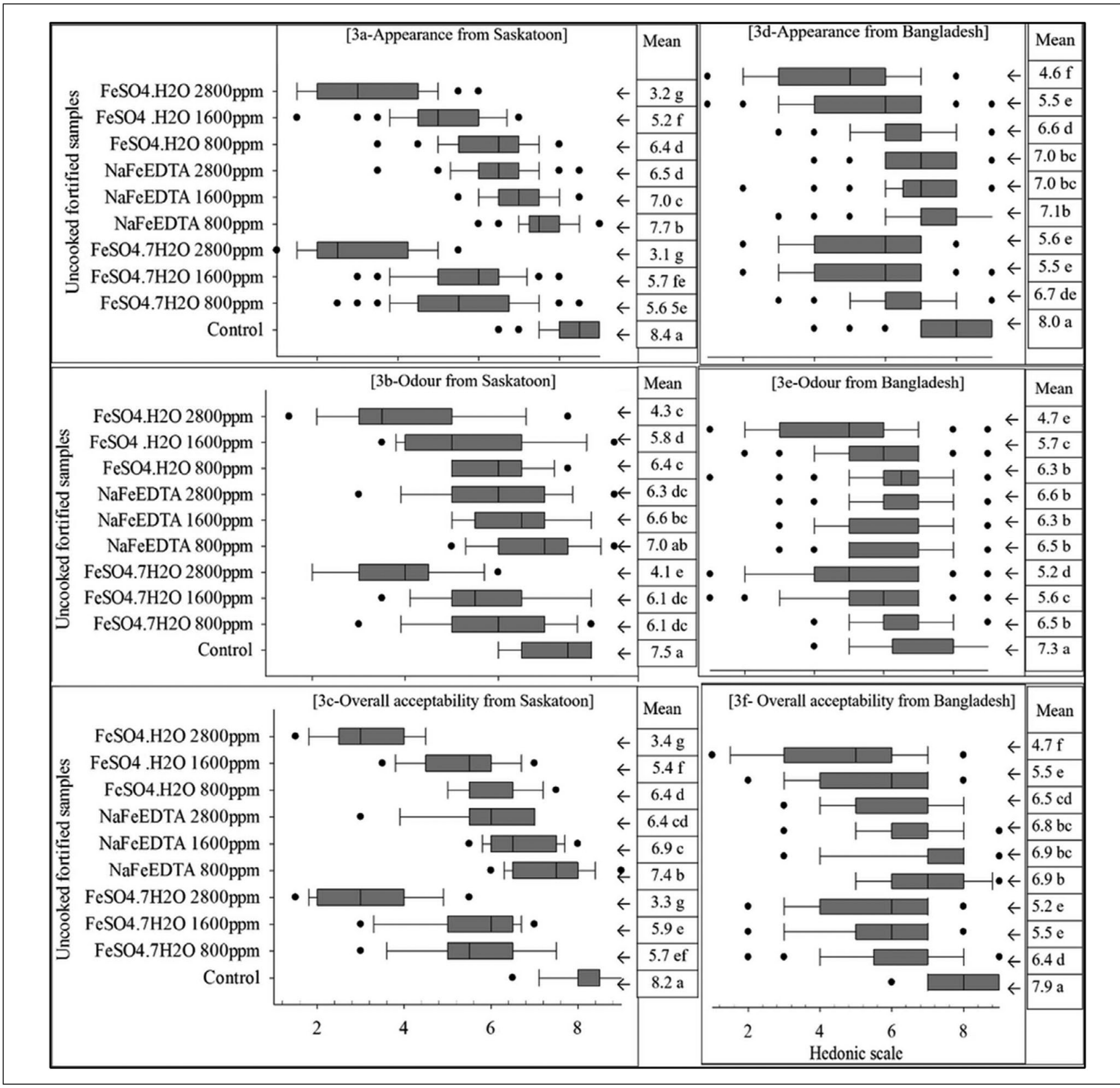

Figure 3–Box plot analysis of hedonic scores obtained for ten uncooked lentil dal samples (3 fortificants × 3 Fe concentrations (800, 1,600, and 2,800 ppm) plus one unfortified control) evaluated for appearance (A, D), odor (B, E), and overall acceptability (C, F) by 45 and 98 panelists in Saskatoon (A to C) and Bangladesh (D to F), respectively. Different letters after mean values indicate significant differences between treatments ($P < 0.05$). A 9-point hedonic scale (1 = dislike extremely to 9 = like extremely) was used.

In general, the box plots for the control sample had a smaller range and less dispersion than those for the nine fortified samples. The box plot either skewed either to the right (positive skew) or was neutral for nearly all samples fortified with NaFeEDTA, with the average score being significantly ($P < 0.05$) lower than those of $FeSO_4{\cdot}7H_2O$- and $FeSO_4{\cdot}H_2O$-fortified samples. The boxplots for the NaFeEDTA-fortified samples (800 and 1,600 ppm Fe) either skewed to the right (positive skew) or were neutral (except for the NaFeEDTA-fortified lentil sample fortified with 2,800 ppm Fe) and their mean values were significantly different ($P < 0.05$), but closer to the control compared to samples fortified with $FeSO_4{\cdot}7H_2O$ or $FeSO_4{\cdot}H_2O$ for all three attributes at both locations.

Sensory response to the attributes of cooked, fortified lentil dal

Significant variation in acceptability was observed for the 4 cooked lentil dal samples evaluated by panelists at both locations (Figure 4). In Saskatoon, the unfortified cooked sample received the highest mean score for all five attributes. In Bangladesh, the NaFeEDTA- and $FeSO_4{\cdot}7H_2O$- fortified samples received the highest scores for appearance and overall acceptability, respectively. Again, the NaFeEDTA- and $FeSO_4{\cdot}7H_2O$- fortified samples received the highest scores for both taste and texture. Odor was scored highest for the unfortified control and $FeSO_4{\cdot}7H_2O$ -fortified samples. The numerical differences between scores across all samples for the five attributes were small. Specifically, the box

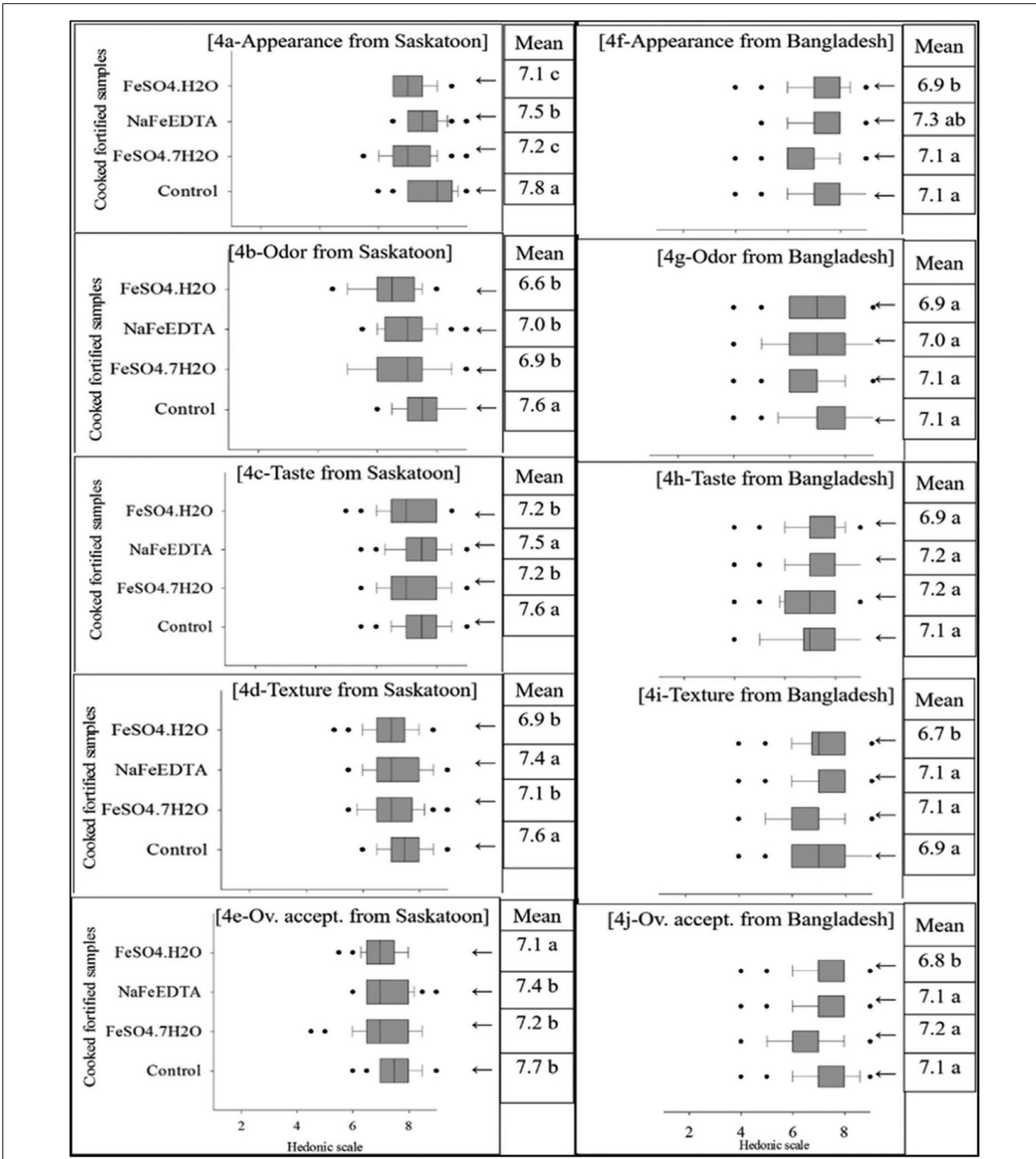

Figure 4–Box plot analysis of hedonic scores obtained for 4 cooked lentil samples (3 fortificants at one Fe concentration (1,600 ppm) plus one unfortified control) evaluated for appearance (A, F), odor (B, G), taste (C, H), texture (D, I) and overall acceptability (E, J) by 45 and 98 panelists in Saskatoon (A to E) and Bangladesh (f to j), respectively. Different letters after mean values indicate significant differences between treatments ($P < 0.05$). A 9-point hedonic scale (1 = dislike extremely to 9 = like extremely) was used.

plots for cooked samples for both locations showed less dispersion and a narrower range of sensory scores for all attributes compared to those for the uncooked samples. All samples scored well (above 6.0) for all five attributes. In Bangladesh, there were no significant differences between scores for control and NaFeEDTA- and $FeSO_4{\cdot}7H_2O$- fortified samples for appearance, texture, or overall acceptability. In Saskatoon, mean values for the NaFeEDTA-fortified samples were consistently the closest to the mean value for the control sample. Both the $FeSO_4{\cdot}7H_2O$- and $FeSO_4{\cdot}H_2O$-fortified samples were significantly different than the control for all attributes, with the exception of the overall acceptability of $FeSO_4{\cdot}7H_2O$-fortified samples.

Table 2–Internal Consistency Reliability (CA) of the sensory panellists' rating of uncooked red lentil and cooked dal samples in Saskatoon and Bangladesh.

	Location	
Treatment	Saskatoon	Bangladesh
Uncooked samples		
Control	0.86	0.88
$FeSO_4 \cdot 7H_2O$-fortified lentil (800 ppm)	0.66	0.86
$FeSO_4 \cdot 7H_2O$-fortified lentil (1600 ppm)	0.88	0.91
$FeSO_4 \cdot 7H_2O$-fortified lentil (2800 ppm)	0.87	0.85
NaFeEDTA-fortified lentil (800 ppm)	0.81	0.80
NaFeEDTA-fortified lentil (1600 ppm)	0.89	0.80
NaFeEDTA-fortified lentil (2800 ppm)	0.86	0.85
$FeSO_4 \cdot H_2O$-fortified lentil (800 ppm)	0.65	0.92
$FeSO_4 \cdot H_2O$-fortified lentil (1600 ppm)	0.80	0.92
$FeSO_4 \cdot H_2O$-fortified lentil (2800 ppm)	0.85	0.93
All (10) uncooked samples [a]	0.93	0.94
Cooked samples		
Control	0.90	0.93
NaFeEDTA-fortified lentil (1600 ppm)	0.85	0.92
$FeSO_4 \cdot H_2O$-fortified lentil (1600 ppm)	0.79	0.93
$FeSO_4 \cdot 7H_2O$-fortified lentil (1600 ppm)	0.89	0.91
All (4) cooked samples [a]	0.88	0.92

[a]Cronbach's alpha scores for all the ten uncooked and 4 cooked samples.

Consistency assessment for sensory data based on CA

CA scores for all uncooked and cooked (both fortified and unfortified) samples are presented in Table 2. The CA scores for the ten uncooked samples were all greater than 0.75 with two exceptions, -$FeSO_4 \cdot 7H_2O$-fortified lentil (800 ppm; 0.66) and $FeSO_4 \cdot H_2O$-fortified lentil (800 ppm; 0.65). In Bangladesh, all samples had CA scores above 0.80. The overall mean CA scores for all variables for the uncooked samples were 0.93 and 0.94 for Saskatoon and Bangladesh, respectively.

Discussion

Sensory analysis originated in the mid-19th century and is considered a multidisciplinary science of various knowledge areas, including food science, psychology, sociology, statistics, human physiology, and food preparation practices (Stone & Sidel, 2004). Sensory attributes are considered the most critical determinants of consumer acceptance of food (Guinard, 2004). In this study, sensory evaluation was considered a key means of understanding and evaluating the overall acceptance of iron-fortified lentil among panelists. The goal was to identify the best fortificant for lentil dal based on consumer preference.

Significant sensory differences were evident among the uncooked samples in both locations. Overall, scores for all sensory attributes and overall acceptability decreased with an increasing concentration of Fe in the fortificant, regardless of type. In Saskatoon, mean scores of the uncooked samples ranged widely, from 3.1 to 8.4, 4.1 to 7.5, and 3.3 to 8.2 for appearance, odor, and overall acceptability, respectively. For all attributes, the control sample and the $FeSO_4 \cdot 7H_2O$-fortified sample (2,800 ppm Fe) had the highest and lowest mean scores, respectively. In Bangladesh, the corresponding scores fell into narrower ranges, from 4.6 to 8.0, 4.7 to 7.3 and 4.7 to 7.9 for appearance, odor, and overall acceptability, respectively. For all attributes, the control sample and samples fortified with $FeSO_4 \cdot H_2O$ (2,800 ppm Fe) received the highest and lowest scores, respectively. These mean scores indicate that panelists evaluated the uncooked samples from "dislike moderately, score of 3" to "like very much, score of 8" in Saskatoon, and "neither like nor dislike, score of 5" to "like very much, score of 8" in Bangladesh. Moreover, in both locations, several panelists gave the highest hedonic score (like extremely, score of 9) for overall acceptability to the unfortified control and 2 NaFeEDTA-fortified samples (800 and 1600 ppm Fe). Overall, these results indicate that fortification with Fe did not have large adverse effects on the acceptability of uncooked lentil to panelists. In particular, NaFeEDTA fortification did not change the visual organoleptic characteristics as much as did the other fortificants at any concentration.

Significant sensory differences were evident for the cooked lentil samples at the two study locations. The average scores for all attributes showed that panelists from Saskatoon assigned a wider range (6.6 to 7.8) of scores than did those from Bangladesh (6.7 to 7.3). This might be due to the fact that the geographical origin of the panelists in Saskatoon was much wider compared to those in Bangladesh. All panelists in Saskatoon were immigrants to Canada, having lived there for 3 to 25 years and having adopted more diverse food habits. Fifty percent of the Bangladeshi panelists in Saskatoon immigrated to Canada more than 5 years ago (data unpublished). Their food habits may have changed over time, which could affect their evaluations. To determine if this was the case, T-tests for unequal sample sizes were performed on data for panelists from Bangladesh ($n = 98$) and the Bangladeshi panelists who participated in Saskatoon ($n = 20$). Scores were statistically different for 5, 3, and 4 of the 10 uncooked samples for appearance, odor, and overall acceptability, respectively (Table S1). Bangladeshi panelists from Saskatoon scored all five attributes of the cooked samples higher (Table S2) than did panelists from Bangladesh, except for samples fortified with $FeSO_4 \cdot 7H_2O$, for odor, taste, texture, and overall acceptability.

The other major group of panelists from Saskatoon was originally from India ($n = 15$). T-test results indicated no significant difference in scoring for most attributes for both uncooked and cooked samples compared to the Bangladeshi panelists, that is, Bangladeshi and Indian panelists from Saskatoon scored samples similarly (Table S3 and S4). Although all panelists from Saskatoon in this study were familiar with lentil and the lentil soup prepared and served for the evaluation, some cultural factors may have influenced their scoring. Yao, Lim, Tamaki, Ishii, Kim, and O'mahony, (2003) reported that ranges in hedonic scores differed for two groups of participants when evaluating the same food product, with a wider range obtained for Japanese compared to Korean panelists. These authors also reported a cross-cultural effect on hedonic ratings when evaluating bulgogi (Korean traditional barbecued beef) with panelists from Korea and the U.S. (non-Korean). Verbeke (2005) reviewed and stated that socio-cultural differences, education status, gender, and annual income had an effect on choice of functional foods at the consumer level. Yao et al., (2003) again reported an effect due to translation of the evaluation form on scoring the same food by panelists from different countries. To mitigate this effect, the sensory evaluation forms, consent forms and questionnaires used in Bangladesh were translated into Bangla (and back-translated to English) to ensure the meaning was consistent with the English version of the forms used in Saskatoon. Despite this effort, the effect of translation might have been a factor in the narrower ranges of scores for the four cooked samples observed in Bangladesh compared to Saskatoon.

In this study, we selected four (three fortified and one control) lentil samples for the sensory acceptability study of cooked lentil dal. The 3 fortified lentil samples were fortified using an Fe concentration of 1,600 ppm for each of the three fortificants. According to the FAO (2017), the desirable intake of pulses is

50 g/day/person and the WHO and FAO recommended Estimated Average Requirements (EARs) for Fe at 10% bioavailability are 29.4 and 10.8 mg/day for 19 to 50 year-old females and males, respectively (WHO & FAO, 2006). Our previous study showed that 50 g of fortified lentil could provide more than 10 mg of Fe, which could meet a major part of the EARs (Podder et al., 2017). In the same study, the lightness (L*), redness (a*), and yellowness (b*) of 10 uncooked samples were measured using a HunterLab instrument (Hunter Associates Laboratory Inc., Reston, Va., U.S.A.). When the sensory data of 3 attributes (appearance, odor, and overall acceptability) of ten uncooked lentil samples obtained from both Saskatoon and Bangladesh were correlated with the L^*, a^*, and b^* scores using Pearson's correlation test, the results were significant at $P < 0.001$ with a range from 0.88 to 0.97 (Table S5).

Another point of interest was whether consumer acceptance was the same for uncooked and cooked samples. A comparison of the scores for the four samples that were considered in both the cooked and uncooked panels showed that the relatively wide range in scores observed for the three uncooked fortified samples narrowed considerably after cooking. Beinner, Soares, Barros, and Monteiro (2010) observed no significant differences between cooked conventional and Fe-fortified rice after conducting sensory evaluation. Hof (2006) conducted a consumer acceptance test with extruded samples of rice fortified with Vitamins A and C and two minerals, Fe and Zn, and unfortified rice and two commercial samples of rice. The vitamin and mineral fortification did not affect sensory acceptability except for some appearance attributes. The reduced sensory variation in the cooked lentil samples in this study might be due to the ingredients in the traditional recipe employed, which was typical for south Asian countries, including Bangladesh. The yellowness of turmeric (*Curcuma longa* L.) powder would reduce the darkness, and the pungent aroma of onion (*Allium cepa* L.) could affect the taste and odor profile of cooked dal prepared with fortified lentil.

Sensory measurements of any food product characteristics should be done carefully by following impartial presentation of the samples to the subjects, eliminating response bias, and using appropriate methods to improve the ability of panelists to evaluate (Delwiche, 2009). Panelists from Saskatoon had at least a high school diploma, but in Bangladesh, approximately 7% of the panelist had no high school diploma or did not attend school. This could be a limitation in this study with respect to representing participants from all socioeconomic levels. In this study, panelists from both locations had no practical or theoretical knowledge of processing and fortifying lentil with Fe. They used their own perceptions to score the control and fortified samples without any bias. The sensory study in both locations showed that panelists could very easily discriminate fortified dal from the control when uncooked; however, panelist preferences were far more similar among the cooked samples. The addition of the recipe ingredients likely helped to maintain the traditional dal or soup colors and flavors within the range of acceptability.

The effect of fortification on sensory attributes of lentil dal should be minimized to achieve the greatest consumer acceptability. Taste, flavor, appearance, and texture are important factors for acceptability and consumption of any product. The effects of Fe fortification on sensory properties of food are highly variable, and depend on the specific Fe fortificant and food item (WHO & FAO, 2006). This includes potential changes in taste, color, and vitamin content (for example, reduced vitamin C, which is an important factor for absorption and utilization of Fe; Mehansho, 2006). Some natural food components such as anthocyanins, tannins, and flavonoids can react with Fe and cause rancidity and other flavor changes (Bovell-Benjamin & Guinard, 2003). For instance, ferrous salts are more soluble and reactive than ferric salts with food components (Richardson, 1990). In this study, the sensory evaluation indicated that NaFeEDTA-fortification minimally affected consumer perception of color, taste, texture, odor, and overall acceptability of cooked lentil. This aligns with the results of our companion study in which appearance measurements using a Tristimular colorimetric scale (Wrolstad & Smith, 2010) resulted in the highest scores for the unfortified control samples, followed by the NaFeEDTA-fortified lentil sample (1,600 ppm Fe; Podder et al., 2017).

Several studies illustrate the advantages of using NaFeEDTA as an Fe fortificant. For instance, NaFeEDTA has been approved as a safe fortificant by the FAO/WHO Expert Committee on Food Additives to fortify foods (WHO, 2000). Moreover, the use of NaFeEDTA is preferred over ferrous sulphate, especially for pulse crops such as lentil that contain phytic acid, an antinutritional component (Hurrell, 2002). NaFeEDTA is highly soluble in water and bioavailable, which allows more concentrated fortificant solutions to be used. Its color also remains more stable after fortification because EDTA is stable to heat and humidity (Davidsson, Dimitriou, Boy, Walczyk, & Hurrell, 2002).

CA was used to evaluate the reliability of the sensory data. CA can be calculated easily with simple statistical analysis, and it considers both the variance and covariance relationships between panelists, creating a "proximity measure between evaluation profiles" (Pinto et al., 2014). The CA value for all treatments (both cooked and uncooked) showed that the fortified lentil dal and the control sample did not differ in context for all attributes, except for 2 samples in Saskatoon. This might be due to panelist inconsistency in scoring the samples. For instance, some panelists missed scoring some attributes for uncooked samples, which was considered as missing data. The missing values can affect the psychometric properties of the test (Huisman, 2000). Overall, however, the CA value indicated that panelists were highly consistent in evaluating all samples using the hedonic scales. The box plot for both uncooked and cooked lentil samples from both locations showed a few outliers which indicated that some panelists disliked the samples extremely. A few panelists commented that there was an oily smell associated with fortified lentil, and some noted a black spot in the region of the micropyle (where the whitish tip of the root of the embryonic seedling is visible when the lentil seed is dehulled. It is part of the embryonic seed axis which is activated early in the germination process when the seed initially absorbs water). In dehulled seed, the root embryo tissue in this area absorbs liquid in the crevice formed between the embryonic root and the cotyledons, resulting in a slight discoloration caused by oxidation of the iron after the fortification process is completed.

The choice of Bangladesh as a study site is strategically important. In Bangladesh, international and national organizations are actively collaborating with the national health sector in conducting studies with fortified foods. Salt and vegetable oil fortified with iodine and vitamin A, respectively, are becoming available in the Bangladeshi market (Ahmed, Prendiville, & Anuradha, 2016). Moreover, efficacy studies are being conducted with staple foods like rice, wheat flour, and sugar fortified with different micronutrients, including Fe. Lentil is considered a nutrient-dense, staple food, consumed daily as the cheapest source of protein, fiber, and micronutrients in South Asian countries, especially in Bangladesh. An acceptability trial carried out by the authors (Yunus et al., unpublished) in Bangladesh showed that adolescent girls of varying ages willingly consume lentil. A major population (approximately 30%) of the adolescent girls in Bangladesh are anemic and Fe deficiency is considered the main cause (Ahmed et al., 2010). About 80% of the population in Bangladesh consumes Canadian lentils and are familiar with their quality. "Dal vaat" (rice and lentil or other pulses) is a common, highly acceptable part of meals in Bangladesh. A recent study revealed that 60% and 12% of Bangladeshi women consume lentil for 3 and 4 days per wk, respectively (Sheema et al., 2016). The dish "hotchpotch" (made with rice and other pulses, mainly lentil) is a typical meal for 1 to 5-year-olds and school-aged children in South Asian countries. A study with 384 rural women in Bangladesh reported that 92% of the respondents eat hotchpotch at least once per week (Sheema et al., 2016). An advantage with fortified lentil lies in the likelihood that all lentil could be centrally processed and fortified, ensuring wide coverage with high quality. This benefit also would improve food quality, which is one of the biggest challenges. Rice is the primary staple food in Bangladesh. Unlike rice, there is no seasonal sporadic production of lentil which can lead to seasonal supply disruption. Also, there are many different varieties of rice, and household preferences are variable. Thousands of millers are involved in the rice supply system, and a significant proportion of the population consumes their own production. In Bangladesh, rice is also fortified and marketed by Nutrition International. To our knowledge, the World Food Programme does not enter commercial market channels and provides fortified products to vulnerable populations only.

The consumption rate of lentil in Bangladesh is 12 g/day/person (Sarker et al., 2004), far below the desirable intake rate of 50 g/day/person on the basis of previous results and current consumption patterns of the Bangladeshi population (FAO, 2017). A small amount of fortified lentil can provide a significant RDA of Fe for a human. Results from this study showed that the uncooked NaFeEDTA-fortified lentil samples (using 2,800 ppm Fe) had similar acceptance for all measured attributes compared to the samples fortified with 800 or 1,600 ppm of Fe. Thus, even a reduced per capita lentil intake could provide a same amount of Fe from lentil fortified with 1,600 ppm of Fe (Podder et al., 2017). In conclusion, Fe-fortified lentil can effectively and economically provide part of the solution to Fe micronutrient deficiency by providing a substantial amount of Fe from a minimum amount of lentil dal.

Conclusions

Lentil is consumed regularly as a staple food in all south Asian countries, where a significant percentage of the population suffers from Fe deficiency. Lentil contains a significant amount of non-heme Fe compared to other major cereals and legumes, all of which have low Fe concentration and low bioavailability. Our previous study illustrated that lentil is a potential vehicle for Fe fortification. In this study, panelists' acceptability scores were higher for NaFeEDTA-fortified samples compared to $FeSO_4{\cdot}7H_2O$- and $FeSO_4{\cdot}H_2O$-fortified samples. Although a significant difference in acceptability was observed between the control and NaFeEDTA-fortified lentil samples in the uncooked condition, the nonsignificant difference in the cooked condition indicates that fortification of lentil with NaFeEDTA is a promising approach. Moreover, the nonsignificant difference between the samples fortified with 800 ppm vs. 1,600 ppm of Fe from NaFeEDTA in the uncooked condition, and the acceptance of the 1,600 ppm samples in the cooked condition, indicate that the 1,600 ppm concentration should be used in lentil fortification. At this level, 11 to 12 mg of dietary Fe can be obtained by consuming 50 g of fortified lentil, well within the normal range of daily consumption. This amount should meet the major part of the estimated average requirements for Fe of target populations.

Acknowledgments

The authors would like to acknowledge financial assistance received from The Saskatchewan Ministry of Agriculture (Agriculture Development Fund) and Grand Challenges Canada. The authors are grateful for technical assistance provided by B. Goetz, Crop Development Centre, Univ. of Saskatchewan. Thanks to Dr. Kuntal Kumar Saha, Dr. Sabiha Sultana, Lima Chowdhury, Dr. Syed Imran Ahmed, and Md. Rajibul Islam from the James P. Grant School of Public Health, BRAC Univ., Dhaka, Bangladesh, for invaluable support in conducting the sensory trial in Bangladesh. Acknowledgement also goes to all of the panelists who participated in this study.

Authors' Contributions

R. Podder, S.M. Khan, P.J. Shand, and C. Jalal designed the study. R. Podder and S.M. Khan conducted the study and collected and analyzed the data. The manuscript was drafted by R. Podder. B. Tar'an, R. T. Tyler, C.J. Henry, C. Jalal, P.J. Shand and A. Vandenberg helped to interpret the data, edited the draft, and reviewed all documents critically, and approved the final manuscript for submission to the Journal.

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Supporting Information

Additional Supporting Information may be found in the online version of this article at the publisher's website:

Table S1. *T*-tests results for sensory evaluation data for 10 uncooked and 4 cooked lentil samples evaluated by panelists from Bangladesh ($n = 98$) and Bangladeshi panelists who participated in Saskatoon ($n = 20$).

Table S2. Average score for sensory evaluation data for ten uncooked and 4 cooked lentil samples evaluated by panelists from Bangladesh ($n = 98$) and Bangladeshi panelists ($n = 20$) who participated in Saskatoon.

Table S3. *T*-tests results for sensory evaluation data for 10 uncooked and 4 cooked lentil samples evaluated by panelists from Bangladesh ($n = 20$) and India ($n = 15$) who participated in Saskatoon.

Table S4. Average scores for sensory evaluation data for ten uncooked and 4 cooked lentil samples evaluated by Bangladeshi ($n = 20$) and Indian panelists ($n = 15$) who participated in Saskatoon.

Table S5. Correlation coefficients between sensory acceptability score from both Saskatoon and Bangladesh for 3 attributes of uncooked lentil samples (appearance, odor, and overall acceptability) and colorimetric data (lightness (L^*), redness (a^*) and yellowness (b^*) score) obtained from HunterLab.