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A Randomized Crossover Trial of Acceptability of Quadruple-Fortified Salt in Women and their Households in Southern India

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Abstract

Background: Double-fortified salt (DFS; iron, iodine) improved iron status in randomized trials and was incorporated into India's social safety net programs, suggesting opportunities to address other micronutrient deficiencies.

Objectives: To evaluate acceptability of quadruple-fortified salt (QFS; iron, iodine, folic acid, vitamin B₁₂) in women and their households, using a randomized crossover trial design and triangle tests.

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CONFLICTS OF INTEREST

The authors have no conflicts of interest to disclose related to this manuscript. Findings and conclusions in this report are those of the authors and do not necessarily represent the official positions of the Centers for Disease Control and Prevention, the DRDC, the National Institute of Diabetes and Digestive and Kidney Diseases (NIDDK), the Eunice Kennedy Shriver National Institute of Child Health and Human Development (NICHD), or the National Institutes of Health.

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Declaration of interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Methods: Women 18–49y (n=77) and their households were randomized to receive QFS or DFS in a randomized crossover design over a 3-week period (week 1: QFS/DFS, 2: iodized salt, 3: DFS/QFS). Each week, participants completed a 9-point hedonic questionnaire (1=dislike extremely to 9=like extremely) to evaluate five sensory domains (color, odor, taste, texture, overall acceptability) of the intervention, and remaining salt was weighed using a digital scale. Triangle tests were conducted among women to evaluate sensory discrimination of salt consumed in rice dishes prepared using standardized recipes. Mixed models were used to examine hedonic ratings and salt use; salt type, sequence, and period were included as fixed effects, and household was included as a random effect. Binomial tests were used to evaluate sensory discrimination of salt type in triangle tests.

Results: Mean hedonic ratings for most of the five sensory domains were ≥ 7 (like moderately) and did not differ by salt type (overall acceptability mean [SD]: QFS: 7.8 [0.7] vs. DFS: 7.7 [1.2]; $p=0.68$). Household salt use (weighed) did not differ by salt type. During the 3-week intervention period, weighed salt use and hedonic ratings significantly increased, indicating a period effect independent of salt type or sequence. In triangle tests, rice samples prepared with QFS, DFS, or iodized salt were not distinguishable.

Conclusion: Acceptability of QFS was high, based on individual hedonic ratings and weighed household salt use. Rice dishes prepared with DFS, QFS, and iodized salt were not distinguishable. Findings informed the design of a randomized trial of QFS in this population.

Keywords

Acceptability; folic acid; vitamin B₁₂; periconceptional; trial; fortification; India

BACKGROUND

Lower maternal folate status during the periconceptional period is a well-established risk factor for neural tube defects (NTDs) (1–6). In a meta-analysis of randomized trials, periconceptional folic acid supplementation reduced the risk of recurrence and occurrence of NTDs by approximately 70% (7). Evidence from early trials (3, 8) informed dietary recommendations for folate in the United States (9) and has led to folic acid fortification of flour in over 70 countries (6, 10).

Folic acid fortification has been associated with a reduction in NTDs in national programs (6, 11–18), making it one of the most efficacious and cost-effective public health interventions (19, 20). To date, strategies to fortify staple foods with folic acid have focused on wheat flour (and more recently, maize flour) (11). However, wheat or maize flour are not commonly consumed in some settings, such as Southern India, where the burden of NTDs is estimated to be among the highest globally (21–23). Along with efforts to expand fortification strategies to include additional staple foods (24), there is also increasing interest in targeting other micronutrient deficiencies (25–29) in at-risk populations, including vitamin B₁₂ deficiency, which may be an independent risk factor for NTDs (25, 26, 30, 31) and may lower red blood folate concentrations (32, 33).

Salt is a consistently and universally consumed commodity, independent of socioeconomic status, and is typically centrally processed (34). Together with the success of salt iodization programs, this demonstrates its potential as a vehicle for fortification with micronutrients (35–38). Salt double-fortified with iron and iodine (DFS) was incorporated into India's social safety net programs (39–41) based on evidence from randomized trials (42–51), and has been evaluated for stability and acceptability (45, 52, 53). In randomized trials in women and school-age children, DFS improved biomarkers of iron status, while the impact on anemia has been heterogeneous (42–51); the etiology of anemia is multifactorial and complex and includes both nutrition and non-nutritional factors (54). Fortification strategies with additional micronutrients could address other nutritional causes of anemia in addition to iron.

Quadruple-fortified salt (QFS; iodine, microencapsulated iron, folic acid, and vitamin B₁₂) has been developed (55, 56), and evaluated for stability, organoleptic properties, and consumer acceptability (55, 57, 58). A recent study in Northern India was conducted to evaluate acceptability of a different formulation of multiple-micronutrient fortified salt (zinc + iron, iodine, folic acid, vitamin B₁₂) in prepared recipes at a central research facility (57); although the salt was acceptable under ideal conditions, authors concluded that data from real-world conditions are needed. Using a one-week household-based intervention, another study evaluated the acceptability of multiple-micronutrient fortified salt (iron, iodine, folic acid, vitamin B₁₂) in Tanzania (58), where salt use and dietary differences from India (10, 59) may impact acceptability of multiple-micronutrient fortified salt in common foods. Although some studies using triangle tests have been conducted to evaluate sensory discrimination between foods prepared with DFS and iodized salt (45–47), there is limited research on sensory discrimination between QFS, DFS, and iodized salt, or on acceptability of this salt formulation in this setting.

We are conducting a randomized trial of QFS in Southern India ([NCT03853304](#)) (60). The current study was a first step with the objective to evaluate the acceptability of QFS among women and their households, using a randomized crossover trial design and triangle tests.

METHODS

Study Design and Setting

This study was conducted to evaluate the acceptability of QFS to inform a randomized trial of QFS in Southern India ([NCT03853304](#)) (60). The parent trial is a randomized, double-blind, efficacy trial of QFS, among 1,000 women 18–49 y and their households in Chittoor, Andhra Pradesh (60). The trial design (60), periconceptional surveillance program (61–63), and pre-intervention biomarker survey (61–63) in this study population have been previously described.

The acceptability study of QFS was conducted in two villages adjacent to the trial catchment area and included a 3-week household-based randomized crossover trial and triangle tests at a central research facility to evaluate sensory discrimination between QFS, DFS, and iodized salt consumed in foods.

Study Population

Participants were women aged 18–49 y and their households. Individuals were excluded if they did not meet inclusion criteria for the parent randomized trial (i.e., women 18–49 y, not pregnant, not lactating, healthy [not currently diagnosed with conditions such as malaria, active tuberculosis disease, or COVID-19; no self-reported fever, diarrhea, or vomiting in the last 2 weeks; no chronic conditions requiring daily medications], and planned to remain in the catchment area for the study period), and additional criteria relating to sensory discrimination: no mouth lesions/ulcers, dental work in last 2 weeks, history of middle ear surgery, neurological disorders, recent loss or change in smell or taste, or self-reported food allergies. Among households with >1 eligible woman, one woman was randomly selected using an *a priori* algorithm corresponding to the number of eligible women in the household (e.g., if there were *n* eligible women, order by ascending age and select the *n*th one). Programmatically, other eligible adult household members (18–65 y) were also invited to participate in data collection visits (i.e., triangle test, hedonic questionnaire) to include information on other potential household decision-makers in secondary analyses. Regardless of eligibility criteria for the acceptability study, individuals who self-reported as the primary preparer(s) of food in the home (≥ 18 y) were also interviewed (if different from the selected woman) to specifically collect data on household salt use during food preparation and cooking.

Ethics

The trial protocol was reviewed and approved by the Cornell University Institutional Review Board and the Arogyavaram Medical Centre (AMC) Institutional Ethics Committee and received clearance from the India Council of Medical Research and Health Ministry's Screening Committee. The parent trial was registered at [ClinicalTrials.gov](https://clinicaltrials.gov/ct2/show/study/NCT03853304) (NCT03853304) and the Clinical Trials Registry of India (REF/2019/03/024479). Written consent was obtained from all participants before enrollment; participants who were unable to read were asked to provide a thumbprint in the presence of a literate witness who signed the consent form. The informed consent process was audio-visually recorded, as recommended by the Government of India for clinical trials.

Salt intervention

The micronutrient-fortified premix was manufactured at JVS Foods Pvt. Ltd. in Jaipur, Rajasthan, India, and the salt interventions were blended and packaged locally by Sahayamatha Salt Refinery Pvt. Ltd. in Tamil Nadu, India, using the same protocol as the parent randomized trial (60). For the acceptability study, the three salt intervention arms were each labeled with a randomly assigned color, excluding colors used to label salt in the parent randomized trial; participants and study staff members involved in data collection and field activities were blinded to this assignment. Staff who coordinated salt production and storage were unblinded to the color code assignment but did not participate in data collection or other field activities.

Data collection

Data collection was conducted in the local language (Telugu) at participants' homes and at the central data collection facility at AMC using electronic tablets by trained nurse enumerators (64). Data collection instruments were developed, translated, and piloted as part of preparations for the parent trial, including review for accuracy of pilot data from mock participant profiles and practice interviews with nurse enumerators and for cultural context by local staff members. Revisions prior to data collection included updating available answer options (e.g., methods of salt storage) and standardized scripts on recommended salt use and storage. Revisions after data collection in preparation for the parent trial included refining questionnaires to reduce participant burden while maintaining data quality (e.g., self-reported salt use).

Household Census and Recruitment

A flowchart of household and women recruitment is presented in Figure 1. After informed consent for the household, trained nurse enumerators conducted a household census, including member roster and sociodemographic information (i.e., household income, household dietary diversity score (HDDS; 0 to 12 food groups) (65), household food insecurity access scale (HFIAS) (66); age and sex of household members). Nurse enumerators returned to households with ≥ 1 woman 18–49 years of age for informed consent, screening, and eligibility determination for the QFS acceptability study. During screening, additional household (i.e., salt use) and individual (e.g., marital status, tobacco use, salt use at the table) data were collected. Eligible women (and their households) were provided an appointment for data collection at the central research facility at AMC for triangle tests, and transportation to AMC was provided. After completing the triangle tests, participants and their households were visited to begin the household-based randomized crossover trial.

Triangle Tests: Women of Reproductive Age

Food preparation.—Triangle tests were conducted at the central research facility at AMC to evaluate sensory discrimination between QFS, DFS, and iodized salt consumed in foods prepared using standardized recipes. Food dishes (i.e., plain rice, lemon rice) were selected for the triangle tests because they were commonly consumed, used in previous sensory tests for DFS (45), and required addition of salt at different points during the cooking process (i.e., salt was added prior to cooking for plain rice, and after cooking for lemon rice) to allow for evaluation of sensory discrimination after different durations of heat exposure. Rice dishes were prepared in batch each day using standardized recipes by the same two staff members (GKR, JMP) to ensure consistency, and ingredients were pre-weighed using scales to the nearest 0.1 gram. Samples of plain rice and lemon rice were weighed and served to participants in clear 4-ounce plastic containers (67).

Blinding and randomization.—In order to maintain blinding, all ingredient containers, utensils, and vessels in the kitchen for different salts (i.e., QFS, DFS, iodized salt) were maintained separately and labeled with intervention colors, and staff preparing the food and administering the triangle tests were blinded to the color code assignments. For the

triangle tests, sample containers were labeled with a three-digit number; each salt (i.e., QFS, DFS, iodized) was assigned 12 random three-digit intervention codes so that no code was repeated for a participant during the study. Randomization lists for the triangle test [i.e., tray arrangements, pair-wise comparisons, three-digit codes] were generated *a priori* by a statistician otherwise unaffiliated with the study (LMJ). Designated staff members placed labeled containers in the appropriate arrangement on each tray and had no interaction with participants.

Triangle Test Administration.—Participants were provided a tray with three samples of a single food dish (i.e., three samples of plain rice or three samples of lemon rice) simultaneously: two samples were prepared with the same type of salt (e.g., QFS, DFS, or iodized salt) while the third sample was prepared with a different type of salt (Figure 2). The objective of the triangle tests was to evaluate sensory discrimination of the salt type (i.e., to identify which sample was different). Participants completed trays for the three pair-wise comparisons (i.e., QFS vs. DFS, QFS vs. iodized salt, DFS vs. iodized salt) for each of the food recipes (i.e., plain rice, lemon rice), for a total of six trays. Participants were randomized to the order of tray arrangements (i.e., AAB, ABA, BAA, BBA, BAB, ABB) and pair-wise comparisons (i.e., QFS vs. DFS, QFS vs. iodized salt, DFS vs. iodized salt), based on an *a priori* randomization list. Within each pair-wise comparison, participants received plain rice first and lemon rice second.

Participants received trays one at a time, with a 5-minute break after three trays. Prior to the triangle test, participants were asked to taste each sample, pausing between each sample to rinse their mouths with water that was provided. Participants tasted samples alone in a room and were asked to place the sample that was different off of the tray, and signal to the enumerator they were finished. After a participant completed a tray, the 3-digit number for the selected sample was recorded, and participants were asked to rate how different the sample was from the others (i.e., degree of difference: slight, moderate, or high), and any additional comments on whether they perceived a difference in specific domains (e.g., color, taste, texture, odor) were recorded.

Household-Based Randomized Crossover Trial

Randomization and Allocation.—After participants completed the triangle tests, their households were randomized to receive QFS or DFS in a crossover design over a 3-week period (i.e., week 1: QFS or DFS, week 2: iodized salt, week 3: DFS or QFS). All households received iodized salt during the second week as a washout period, to allow households to finish consuming foods made with the intervention salt provided during the first week. Randomization lists for the crossover trial were generated *a priori* by a statistician otherwise unaffiliated with the study (LMJ). Each week, households received salt in a 500-gram bag, labeled with one of three intervention color codes but otherwise identical, and an opaque plastic container for storing salt; households also received a set of measuring spoons for salt use during cooking. Assuming approximately 10 grams of salt consumed per person per day (68) with an average of four household members (69), one 500-gram bag of salt was estimated to be sufficient for food preparation for one week and no additional bags were provided before the next intervention week.

Households were visited once per week to deliver the intervention salt and container, collect and weigh salt remaining from the previous week, and administer questionnaires in person (or *via* telephone, as needed). Trained nurse enumerators provided information to participants on recommended salt use and storage practices, and information on hygiene and food safety using a standardized script. Participants were requested to use the salt in food preparation and at the table, and to not use the salt for other purposes. Enumerators recommended storing the intervention salt in a sealed container away from the stove or other heat source, and storing the salt that they usually used in the household in another location to prevent accidental use during the study period.

Salt use.—Household and individual-level salt use during the crossover study was evaluated using salt weighing and questionnaires. Salt was weighed in triplicate prior to delivery and at the end of each week using a tared digital scale to the nearest 0.1 gram. Total household salt use was defined as the difference in weight of salt provided at delivery and at the end of each week. Daily household salt use was defined as total household salt use divided by the number of days between visits. The total number of individuals who consumed meals at the household each week was calculated based on the reported number of household and non-household members ≥ 5 years of age consuming meals in the past seven days. Salt use per person per day was defined as daily household salt use divided by the total number of individuals ≥ 5 years of age (both household members and non-household members) who consumed meals at the household each week, excluding households in which the number of individuals who ate at the household was missing. If the number of individuals who ate at the household was not reported for a given week, salt use per person per day was calculated using the median value of the number of individuals from the other study time points.

Acceptability of Salt Intervention: Hedonic questionnaire.—After each week, participants completed a 9-point hedonic scale (i.e., from 1 = ‘dislike extremely’ to 9 = ‘like extremely’) for five sensory domains: color, odor, taste, texture, and overall acceptability. A printed copy of the hedonic scale was shown to participants each time to ensure consistency in rating. If a participant was not at home, households were revisited (or called) to complete the hedonic form. A printed copy of the hedonic scale was dropped off at households to aid in data collection over the phone.

COVID-19 Precautions

COVID-19 safety precautions were followed throughout the study, in accordance with the regulations of the Government of India, the state of Andhra Pradesh, and the U.S. Centers for Disease Control and Prevention. Participants were screened for self-reported COVID-19 symptoms (*via* phone) before household visits and requested to complete a rapid SARS-CoV-2 antigen test immediately upon arrival at AMC. Study staff and participants were provided masks and requested to wear them during study visits and in-person interviews. Study staff monitored symptoms, and all study staff were instructed to stay home if they had any symptoms or had been potentially exposed to COVID-19 (e.g., travel, contact with someone with COVID-19). Data collection was conducted outdoors and with social distancing, where possible.

Sample Size

Power calculations were conducted *a priori* and replicated by a statistician otherwise unaffiliated with the study (LMJ). For the triangle tests, a sample size of $n=55$ participants would enable detection of a difference at 90% power at $\alpha=0.05$, given a chance-adjusted percent correct of 30% (i.e., effect size parameter) (70). For the randomized crossover trial, a sample size of $n=54$ total households would enable detection of a 0.5-point difference in paired hedonic scale ratings with standard deviation of the difference of 1.1 (i.e., effect size of 0.45), based on mean ratings of DFS and QFS in a rice dish from a previous publication (57), with 90% power at $\alpha=0.05$. Based on these power calculations, we planned to recruit at least 55 women and their households from two pre-selected villages. All eligible households within each village had the opportunity to participate.

Statistical Methods

Descriptive statistics were presented as n (%), mean (standard deviation [SD]), and predicted population margins (least squares mean [SE or 95% confidence interval]). Primary analyses were conducted among women 18–49 y (1 per household); we also conducted analyses in all participating members of the household (i.e., including women and additional household members). Findings were similar, and analyses among women are presented in tables and results.

Triangle test.—Binomial tests with continuity correction were used to evaluate sensory discrimination of salt type in triangle tests (i.e., whether the observed percentage of correctly identified samples was more than the 33.3% expected due to chance). Logistic regression was used to examine self-reported differences in samples between participants who correctly identified the sample versus participants who did not.

Randomized crossover trial.—Linear mixed models with a compound symmetry covariance structure were used to evaluate hedonic ratings and salt use; salt type (QFS vs. DFS), randomization sequence (sequence 1 vs. 2), and period (week 1 vs. week 3) were included as fixed effects, and household was included as a random effect.

Sensitivity analyses.—In sensitivity analyses, salt use was defined as dichotomous variables (≥ 1.0 and ≥ 5.0 g per person per day) and assessed using binomial regression; Poisson distribution was used when models failed to converge. Salt use (as a continuous variable) was evaluated in households that used ≥ 1.0 g per person per day. Statistical analyses were performed using SAS software version 9.4 (SAS Institute, Inc.).

RESULTS

Participant characteristics.

A flowchart of households and women is summarized in Figure 1. A total of 138 households had at least one woman aged 18–49 y. After informed consent and screening, a total of 77 households had at least one woman 18–49 y who was eligible for the randomized crossover trial, and 75 women were eligible for the triangle test. A total of 66 women 18–49 y participated in the triangle tests at our central data collection facility at AMC.

Sociodemographic characteristics.

Characteristics of women and their households are presented in Table 1 and Supplemental Table 1. The mean age of participants was 35 years; most were married (91%) and had at least some formal schooling (84%). A total of 96% of women were the primary food preparer in the household and 96% reported following a non-vegetarian diet. Although the prevalence of tobacco use was low (3%), 35% of women reported using betel nut (i.e., areca nut, a palm fruit commonly chewed in Southeast Asia and classified as a carcinogen (71)) in the past two weeks.

Salt use.

At baseline, approximately half of women reported using salt at the table at least once per day, while 13% reported never adding salt at the table. Most households reported using both table salt and rock salt (82%). Of households that reported purchasing table salt (91%), most reported using it at the table (87%), while 48% used it for cooking. In contrast, of households that purchased rock salt (91%), most reported using it for cooking (97%) and other non-food purposes (87%), and 38% reported adding it at the table.

Triangle test.

Results from the triangle test are presented in Table 2. Food samples (i.e., plain rice, lemon rice) prepared with QFS, DFS, or iodized salt were not distinguishable in pair-wise comparisons (QFS *vs.* DFS, QFS *vs.* iodized, DFS *vs.* iodized; $p>0.05$).

Results from self-reported sensory differences between food samples are presented in Table 3. When asked to describe the difference between the sample they selected compared to the other two samples, most participants (60–79%) reported a slight difference (*vs.* moderate or high). Most (85–97%) participants reported a difference in taste; 5–11% reported a difference in color between QFS or DFS and iodized salt. Self-reported sensory differences were consistent between women who selected the correct sample compared to women who selected the incorrect sample for most comparisons. However, women who selected the correct sample were more likely to report that the samples were slightly different (*vs.* moderate or high) for QFS compared to DFS in lemon rice samples ($p=0.01$), were more likely to report a difference in odor for DFS compared to iodized salt ($p=0.03$) and QFS compared to DFS ($p=0.01$) in plain rice samples, and were less likely to report a difference in taste for QFS compared to iodized salt in lemon rice samples ($p=0.01$).

Household randomized crossover trial: Salt use.

Weighed household salt use by intervention type and by week is presented in Table 4. Total household salt use (mean [SD]; week 1: 145.3 [145.2] g; week 3: 198.9 [175.8] g) and salt use per person per day (mean [SD]; week 1: 6.0 [6.4] g; week 3: 9.1 [7.6] g) increased during the 3-week intervention period. Approximately half (week 1: 50.7%; week 3: 67.2%) of households used ≥ 5 g of salt per person per day, and three-fourths (week 1: 66.2%; week 3: 81.3%) used ≥ 1 g. Among households using ≥ 1.0 g of salt per person per day, salt use (mean [SD]) ranged from 9.0 [5.8] grams per person per day during week 1 to 11.1 [6.9] g during week 3.

Approximately one-fourth of households consumed <1.0 g salt per person per day (week 1: 33.8%; week 3: 18.8%). The most frequently reported reasons for not using salt during the study included traveling or not being home (week 1: n=11; week 3: n=4) and forgetting to use the salt (week 1: n=6; week 3: n=3). Other reasons included household member was sick (week 1: n=0; week 3: n=2), primary preparer of food in the household that week did not know to use the salt (week 1: n=1; week 3: n=1), disliking the salt (week 1: n=1; week 3: n=0), concerns regarding using the salt (week 1: n=3; week 3: n=0), or another household member (e.g., husband, father-in-law) did not permit the household to use the salt (week 1: n=0; week 3: n=3) (data not shown).

Total household salt use, salt use per day, and salt use per person per day, did not differ by salt type (QFS vs. DFS) in mixed models that included fixed effects for salt type, randomization sequence, and period. However, during the study period, salt use (regardless of type of salt) increased from week 1 to week 3, including total household salt use (least square mean difference [MD]: 54.4 g; 95% confidence interval [CI]: 19.3, 89.6; p=0.003) and salt use per person per day (MD: 3.0 g; 95% CI: 1.0, 5.1; p=0.005) (Figure 3), indicating a period effect independent of salt type and randomization sequence. Findings were similar in sensitivity analyses among households that consumed ≥ 1.0 g per person per day.

Household randomized crossover trial: Hedonic ratings.

Hedonic ratings by salt intervention type and week are presented in Table 5 and Figure 4. Acceptability of the salt interventions was high: mean hedonic rating for most of the five sensory domains (color, odor, taste, texture, overall) was ≥ 7.0 (i.e., like moderately) for each salt type. Hedonic ratings did not differ by salt type (QFS vs. DFS) for any of the sensory domains in mixed models that included fixed effects for salt type, randomization sequence, and period. However, during the study period, hedonic ratings significantly increased from week 1 to week 3 for all sensory domains except texture, indicating a period effect independent of salt type and randomization sequence.

DISCUSSION

In this randomized crossover trial, acceptability of quadruple-fortified salt was high, based on weighed household salt use and individual hedonic ratings, and foods prepared with DFS, QFS, and iodized salt were not distinguishable in triangle tests. Findings informed a randomized trial of QFS in this population.

Triangle tests.

In the current study, foods prepared with QFS, DFS, and iodized salt were not distinguishable in triangle tests, and few participants noted differences between foods prepared when salt was added prior to (plain rice) or after (lemon rice) cooking. To our knowledge, no sensory discrimination studies to date have been conducted to evaluate micronutrient-fortified salt formulated using the method in the current study—i.e., DFS or QFS with microencapsulated iron (ferrous fumarate) *via* extrusion—to which findings are directly comparable. However, findings are consistent with a study among women (n=18) in Bangalore, India, that used triangle tests to compare two formulations of DFS

(micronized ferric pyrophosphate and microencapsulated ferrous fumarate *via* fluid bed) with iodized salt, prepared in plain rice, lemon rice, and rice with sambar (vegetable stew) (45). Foods prepared with DFS were indistinguishable from iodized salt except in plain rice, in which DFS at higher concentrations (microencapsulated ferrous fumarate *via* fluid bed; 2 mg iron/g salt) appeared as black specks (45). Findings are also consistent with previous triangle tests conducted among adults in Morocco, comparing traditional foods prepared with formulations of DFS [micronized ferric pyrophosphate (46) and microencapsulated ferrous fumarate *via* fluid bed method (47)] and salt fortified with vitamin A, iodine, and iron using micronized ferric pyrophosphate (72), to iodized salt. To our knowledge, no studies to date have used sensory discrimination tests to evaluate the acceptability of quadruple-fortified salt (i.e., iodine iron, folic acid, and vitamin B₁₂) compared to DFS or iodized salt.

Hedonic results.

In the current study, individual hedonic ratings were high, and did not differ by salt type in any of the sensory domains evaluated. Although other studies have reported high acceptability of multiple micronutrient-fortified salt, color differences were reported. In a 10-month randomized trial among children and their households in Bangalore, India, >98% of surveyed households (n=345) reported that the salt intervention (i.e., DFS with micronized ferric pyrophosphate, DFS with microencapsulated ferrous fumarate *via* fluid bed, *vs.* iodized salt) was acceptable, including color in both damp and dry seasons, taste, and overall acceptability (45). However, households receiving DFS were more likely to report a slight color change in foods (i.e., 26% [DFS with micronized ferric pyrophosphate] or 59% [DFS with microencapsulated ferrous fumarate *via* fluid bed]), compared to iodized salt (4%) (45). Similarly, other randomized trials (8–10 months) in Morocco reported high acceptability but color changes in foods with multiple micronutrient-fortified salt [DFS with micronized ferric pyrophosphate (46); DFS with microencapsulated ferrous fumarate *via* fluid bed method (47); vitamin A, iodine, and iron using micronized ferric pyrophosphate (72)] compared to iodized salt. In a study in New Delhi, India, women (≥18 y; n=26) gave high hedonic ratings (≥3.7 using a 5-point scale) to foods prepared with quintuple-fortified salt (Q5FS; zinc + iodine, iron, vitamin B₁₂, and folic acid) and DFS with microencapsulated ferrous fumarate *via* extrusion, and iodized salt (57). However, Q5FS and DFS had significantly lower ratings for color, compared to iodized salt. Another study in Tanzania provided households (n=899) with one of three salts (QFS [iodine, iron, vitamin B₁₂, and folic acid] or DFS with microencapsulated ferrous fumarate *via* extrusion, or iodized salt, similar to the current study) to use *ad libitum* for a week; 78% of all participants reported the intervention salt to be acceptable (*vs.* neutral or not acceptable) and hedonic ratings did not differ across salt types for all domains evaluated (58). However, the mean hedonic ratings were low (1.5–1.8 using a 5-point scale) across domains for all salt types. Although differences in methods used in previous studies, including study design, target population, salt interventions (i.e., micronutrient composition, formulation, and fortification methods), duration, and setting, constrain direct comparability of findings, the current study also demonstrated high acceptability of QFS.

Salt use.

In the current study, weighed salt use was ~6–9 g per person per day and ~9–11 g among the approximately 75% of households that used ≥ 1 g of salt per person per day. The salt use per person per day was similar to population-based estimates from adults in rural Andhra Pradesh using 24-hour urine sampling (mean [95% CI]: 9.15 [8.73–9.57] g) (68), which were used to inform power calculations in the parent trial. Salt use in the current study was consistent with previous estimates from randomized trials of DFS in India (mean [SD]; 11.3 [5.1] g *via* 4-day weighing at baseline (45); DFS: 12.4 [7.9], iodized salt: 15.0 [13.6] *via* 3-day weighing (42); DFS: 7.4 [4.8], iodized salt: 7.9 [4.9] *via* 24-hour dietary recall (42)). However, the current acceptability study was not designed to quantify individual- or household-level salt use, and its 3-week duration and pilot sample constrain direct comparability to population-based estimates (68) or longer term randomized trials (42, 45).

In this study, 75% of households used ≥ 1 g of salt per person per day and weighed household salt use and hedonic ratings increased over time, indicating a period effect. Perceptions and use of the salt intervention may be impacted by several factors, such as salt use practices, household decision-making, socioeconomic factors, and awareness of the benefits of the intervention salt.

Salt use practices.

Most households in the study population reported using rock salt for cooking (*vs.* table salt which has a comparable texture to the intervention salt), suggesting that households may require an acclimation period for intervention adoption. In the current study, baseline household salt practices (type of salt purchased, use of rock and table salt) were similar between households that used the salt (*i.e.*, ≥ 1 g per person per day for at least 2 weeks) *vs.* non-users (*i.e.*, < 1 g per person per day for at least 2 weeks), and between households that used a higher amount of salt (*i.e.*, ≥ 5 g per person per day for at least 2 weeks) *vs.* low-users (*i.e.*, < 5 g per person per day for at least 2 weeks). In the aforementioned randomized trial of DFS in Bangalore, India ($n=80$; 4-day weighing) (45), salt use at the end of the 10-month study did not differ from baseline; however, usual household salt practices prior to the start of the trial were not reported.

Socioeconomic factors.

Although there is limited research on correlates of salt intervention use, an effectiveness study of DFS in Uttar Pradesh, India, reported that lower wealth quintile was associated with higher DFS adherence (73). In the current study, in secondary analyses households with higher salt use (*i.e.*, ≥ 5 g per person per day for at least 2 weeks) were more likely to have a lower household income ($\leq 10,000$ INR), compared to households with lower salt use (*i.e.*, < 5 g per person per day for at least 2 weeks; 59% *vs.* 31%; data not shown), suggesting households with lower income may use more salt per week compared to households with income $> 10,000$ INR.

Household decision-making.

In the current study, although most women were the primary food preparers in the household, only 13% self-reported as the head of the household. In secondary analyses, women identified barriers to salt use (e.g., such as another household member did not permit the salt to be used in the home, other primary food preparers did not know to use the salt), which may influence decisions regarding salt use and food preparation in the household and are important areas of future research.

Awareness of benefits and sensory perceptions.

In analyses of reasons for not using salt, barriers such as concerns about using the salt and disliking the salt were identified; this is consistent with previous research on barriers for DFS in India's safety net programs, which include low consumer awareness of the benefits, quality, and safety of DFS (52, 73). In the current study, hedonic ratings for overall acceptability were higher among households that used the salt (i.e., ≥ 1 g per person per day for at least 2 weeks) vs. non-users (i.e., < 1 g per person per day for at least 2 weeks), and in households that used a higher amount of salt (i.e., ≥ 5 g per person per day for at least 2 weeks) vs. low-users (i.e., < 5 g per person per day for at least 2 weeks; data not shown).

Findings from this acceptability study informed the parent randomized trial, including counseling households on potential barriers identified, potential benefits of the intervention, how to acclimate from rock salt to table salt for food preparation, and reminders for using the salt to support retention and adherence.

This study contributed additional information on the acceptability of quadruple-fortified salt, using different methods from previous studies (i.e., a randomized crossover trial design and triangle tests), and included participants (women 18–49 y and their households) that are similar to the target population for the parent randomized trial. This study has several limitations. This study was conducted in two villages outside of the trial catchment area and was not a random sample; this may limit generalizability to the catchment area for the randomized trial. The number of triangle tests was limited to prevent sensory fatigue; therefore, we were unable to assess differences in raw salt and other common foods, such as sambar and egg or milk-based dishes in which color changes have been noted in other studies (47, 72). Findings may not reflect sensory discrimination between salt types prepared in other foods; however, hedonic ratings were similar across salt types when prepared in dishes at the household as part of the randomized crossover trial. Although we invited other household members to participate in data collection, we were not able to recruit enough additional household members to conduct sub-analyses within this group. The focus of the randomized crossover trial was to compare intervention arms in the parent randomized trial (QFS vs. DFS); however, including iodized salt in the random allocation would have allowed additional comparisons to evaluate acceptability. Lastly, we assessed weighed salt use and were not able to distinguish how the intervention salt was used (e.g., purposes besides food preparation and at the table) or changes in baseline salt use practices. Weighed salt use increased over a 3-week period; understanding the reasons for the increase and changes in salt use and acceptance beyond three weeks are critical for determining the efficacy of QFS. Although reasons reported for not using the salt (predominantly traveling

or forgetting during the first week) may have contributed to the observed increase, other potential factors, such as using the salt for other purposes or increasing salt consumption above baseline salt intake, were not specifically assessed and could impact the efficacy of the intervention and health in the population. In addition to counseling on salt use for food preparation, participants in the parent trial will receive information on salt reduction per WHO recommendations for sodium intake (60, 74). Adjusting from rock salt to table salt may have had a strong influence on salt use and hedonic ratings; detectable differences between salt interventions (QFS vs. DFS) may require a longer study period beyond three weeks. As part of the parent trial, long-term acceptance and perceptions of using multiple-micronutrient fortified salt within this population will be assessed to further inform public health programs, particularly given the large number of households that reported using rock salt for food preparation.

In summary, in this study, acceptability of quadruple-fortified salt was high, based on individual hedonic ratings and weighed household salt use. Foods prepared with DFS, QFS, and iodized salt were not distinguishable, and intervention salts were highly rated across sensory domains and for overall acceptability. Findings informed the design of a randomized efficacy trial of QFS in this population. The parent randomized trial of QFS (i.e., iron, iodine + folic acid and/or vitamin B₁₂), in 1,000 women and their households, will evaluate the independent addition of folic acid or vitamin B₁₂ compared to DFS on micronutrient status prospectively over 12 months (60). Findings from this acceptability study and the parent randomized trial will inform interventions and public health programs for anemia and birth defects prevention.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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DATA AVAILABILITY

Data described in this manuscript, code book, and analytic code will be made available upon request to the corresponding author.

Abbreviations Used:

AMC	Arogyavaram Medical Centre
95% CI	95% confidence interval
DFS	double-fortified salt
MD	mean difference
QFS	quadruple-fortified salt
SD	standard deviation

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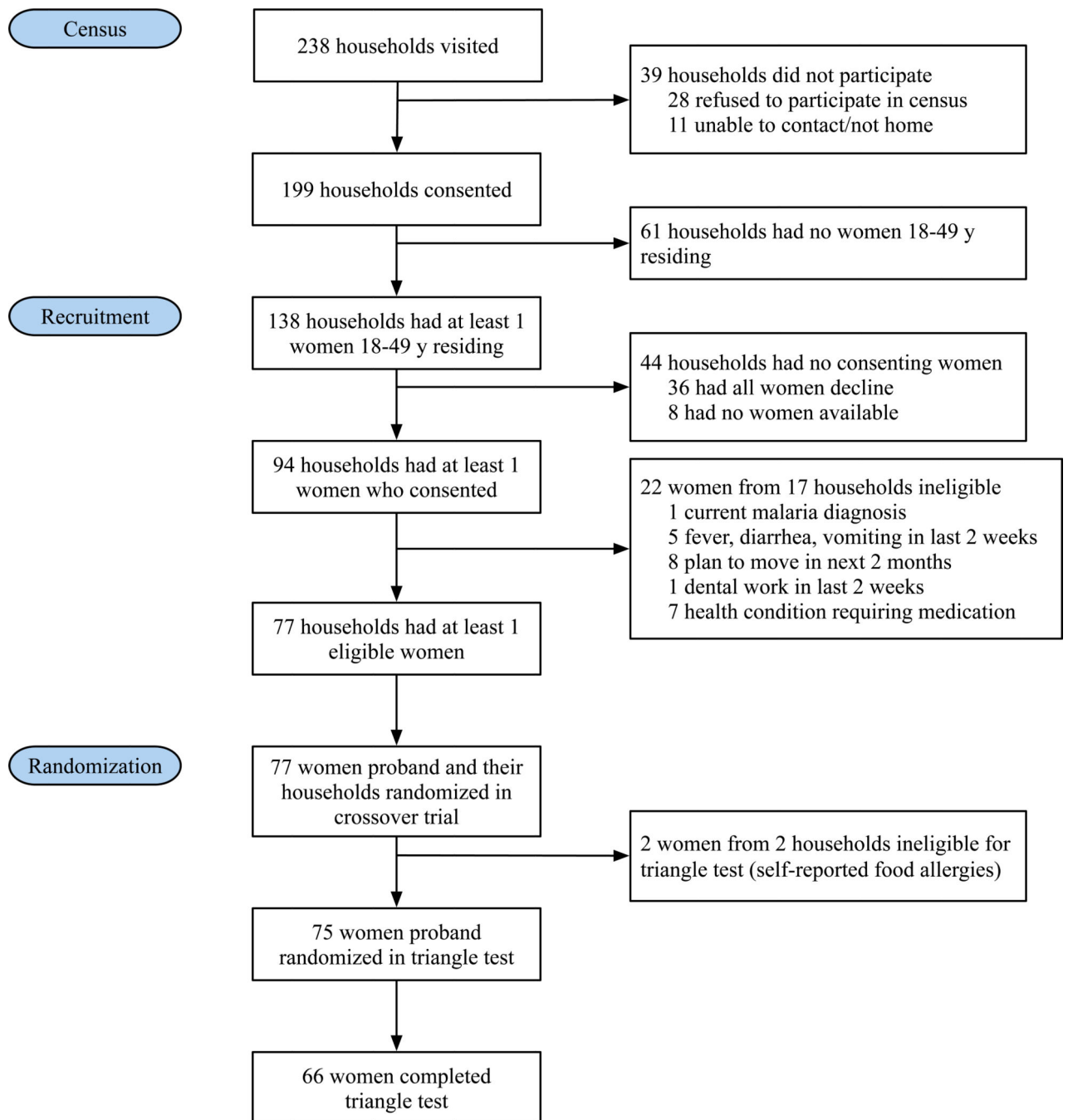


Figure 1.
Participant Flow Chart

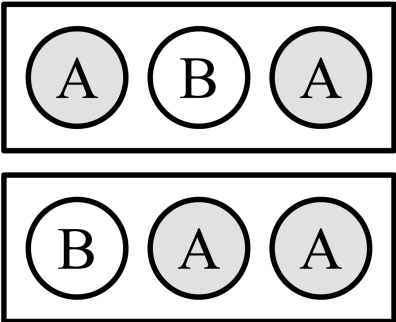
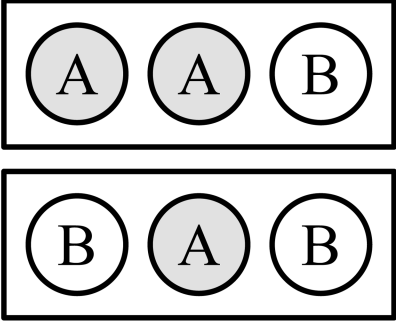
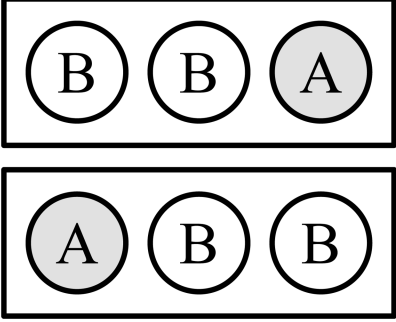
Tray #	Rice dish	Pair-wise combination	Example Tray
1	Plain rice	QFS (A)	
2	Lemon rice	DFS (B)	
3	Plain rice	QFS (A)	
4	Lemon rice	IS (B)	
5	Plain rice	DFS (A)	
6	Lemon rice	IS (B)	

Figure 2.
Triangle Test: Example trays
Participants were randomized to the order of pair-wise combinations (i.e., DFS vs. QFS, QFS vs. iodized salt, DFS vs. iodized salt) and possible tray arrangements (i.e., AAB, ABA, BAA, BBA, BAB, ABB). Within each pair-wise combination, participants received plain rice first and lemon rice second for a total of six trays. Abbreviations: DFS, double-fortified salt (iron, iodine); IS, iodized salt; QFS, quadruple-fortified salt (iron, iodine, folic acid, vitamin B₁₂)

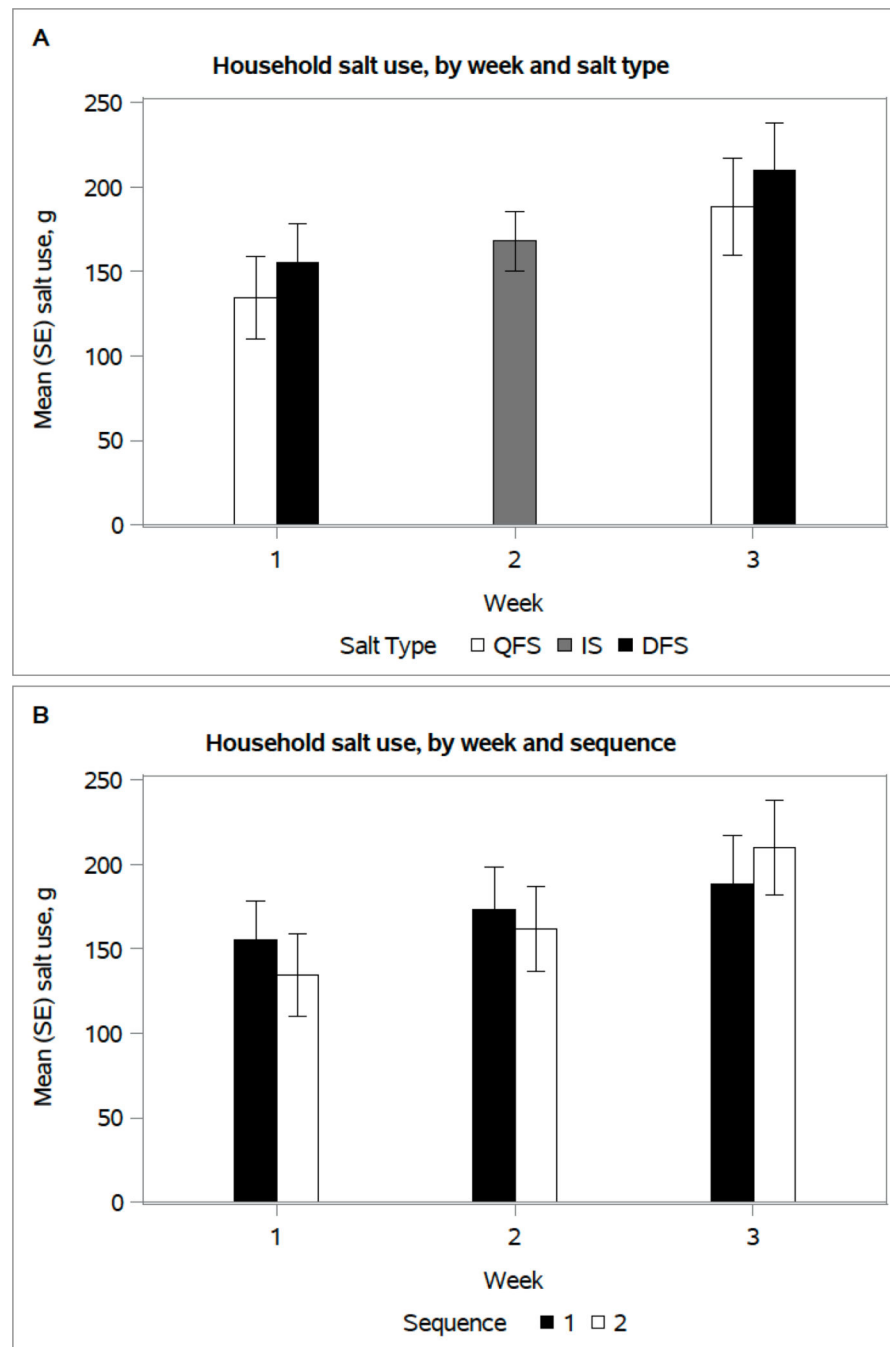


Figure 3. Total household salt use during a randomized crossover trial
Total salt use did not differ by salt type (QFS vs. DFS) or randomization sequence. During the study period, salt use (regardless of type of salt) increased from week 1 to week 3, indicating a period effect independent of salt type and randomization sequence. Abbreviations: DFS, double-fortified salt (iron, iodine); IS, iodized salt; QFS, quadruple-fortified salt (iron, iodine, folic acid, vitamin B₁₂); SE, standard error

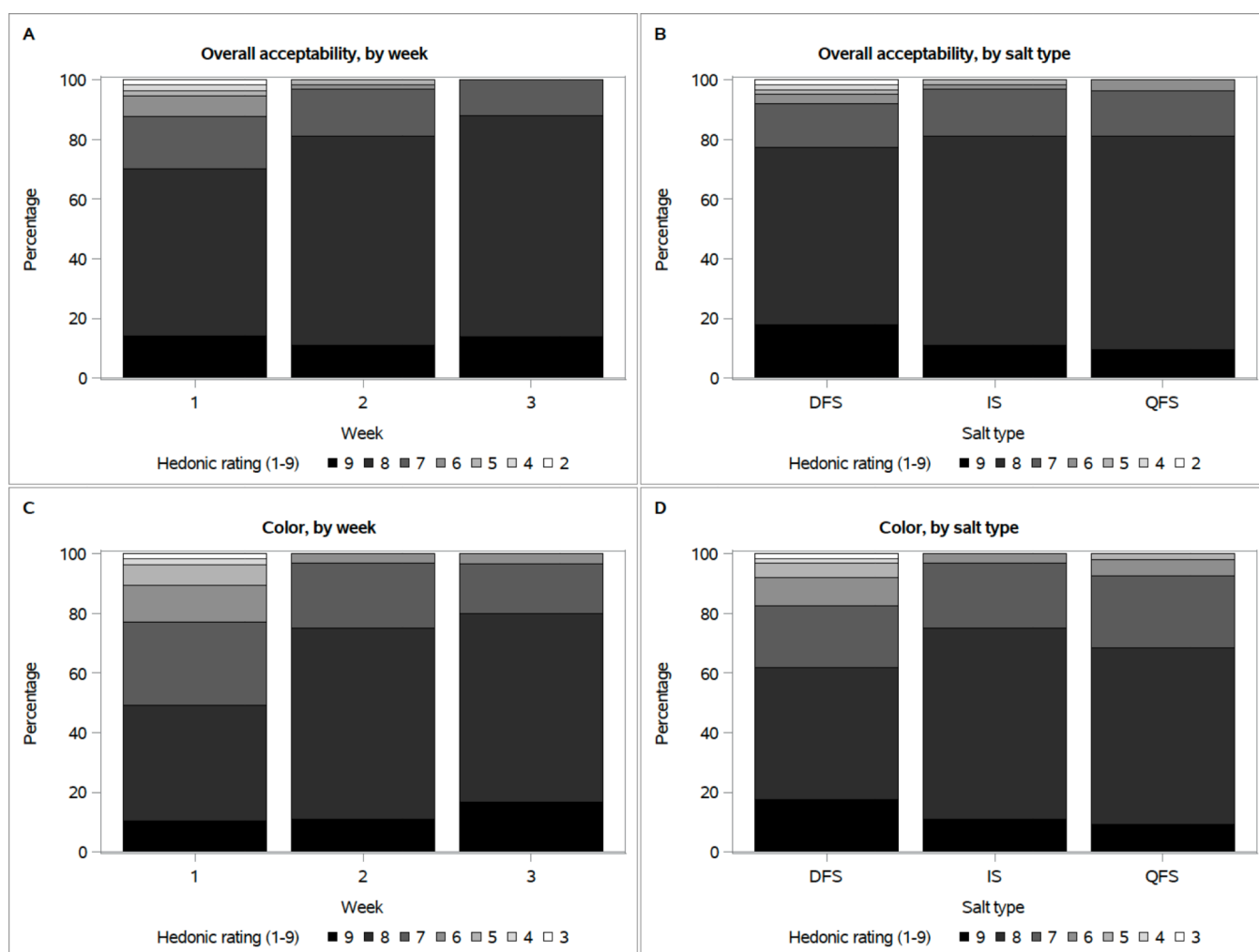


Figure 4.

Hedonic ratings during a randomized crossover trial

Percentage of participants that rated overall acceptability and color on a 9-point hedonic scale (1=dislike extremely to 9=like extremely) are presented. Mean hedonic ratings did not differ by salt type (QFS vs. DFS) or randomization sequence. During the study period, hedonic ratings (regardless of type of salt) increased from week 1 to week 3, indicating a period effect independent of salt type and randomization sequence. Abbreviations: DFS, double-fortified salt (iron, iodine); IS, iodized salt; QFS, quadruple-fortified salt (iron, iodine, folic acid, vitamin B₁₂)

Table 1.

Characteristics of women and their households participating in a randomized crossover trial of acceptability of quadruple fortified salt

	Overall (n=77)		Sequence 1 (DFS-QFS) (n=40)		Sequence 2 (QFS-DFS) (n=37)	
	Mean ± SD or n (%)		Mean ± SD or n (%)		Mean ± SD or n (%)	
Household						
Village						
Village 1	19 (24.7)		13 (32.5)		6 (16.2)	
Village 2	58 (75.3)		27 (67.5)		31 (83.8)	
Household size	4.1 ± 1.3		4.0 ± 1.5		4.2 ± 1.1	
Monthly income, INR ¹	14,067 ± 12,399		14,525 ± 13,208		13,543 ± 11,573	
≤10,000 INR ⁵	34 (45.3)		16 (40.0)		18 (51.4)	
Type of salt purchased by household ²						
Rock salt only	7 (9.2)		5 (12.5)		2 (5.6)	
Table salt only	7 (9.2)		2 (5.0)		5 (13.9)	
Rock salt and table salt	62 (81.6)		33 (82.5)		29 (80.6)	
Rock salt	69 (90.8)		38 (95.0)		31 (86.1)	
Table salt	69 (90.8)		35 (87.5)		34 (94.4)	
Use of salt by household ³						
Rock salt						
Cooking	67 (97.1)		36 (94.7)		31 (100.0)	
At the table	26 (37.7)		17 (44.7)		9 (29.0)	
For other purposes	60 (87.0)		34 (89.5)		26 (83.9)	
Table salt						
Cooking ¹	32 (47.8)		15 (45.5)		17 (50.0)	
At the table	60 (87.0)		30 (85.7)		30 (88.2)	
For other purposes	11 (15.9)		5 (14.3)		6 (17.6)	
Rock salt storage ^{2,3}						
Large plastic container with lid	54 (79.4)		28 (75.7)		26 (83.9)	
Large ceramic/mud pot with lid	0 (0.0)		0 (0.0)		0 (0.0)	
Bowl or other open container	5 (7.4)		4 (10.8)		1 (3.2)	

	Overall (n=77)	Sequence 1 (DFS-QFS) (n=40)	Sequence 2 (QFS-DFS) (n=37)
	Mean ± SD or n (%)	Mean ± SD or n (%)	Mean ± SD or n (%)
Bag	8 (11.8)	5 (13.5)	3 (9.7)
Large plastic container with lid and bag	1 (1.5)	0 (0.0)	1 (3.2)
Table salt storage ^{2,3}	43 (63.2)	23 (67.6)	20 (58.8)
Large plastic container with lid	0 (0.0)	0 (0.0)	0 (0.0)
Large ceramic/mud pot with lid	0 (0.0)	0 (0.0)	0 (0.0)
Bowl/open container	10 (14.7)	4 (11.8)	6 (17.6)
Salt shaker	7 (10.3)	3 (8.8)	4 (11.8)
Bag	1 (1.5)	1 (2.9)	0 (0.0)
Large plastic container with lid and open container	5 (7.4)	2 (5.9)	3 (8.8)
Large plastic container with lid and salt shaker	2 (2.9)	1 (2.9)	1 (2.9)
Cost of salt, INR per kg			
Rock salt ^{3,4}	12.0 ± 3.5	12.2 ± 3.7	11.7 ± 3.3
Table salt ^{1,3}	17.3 ± 4.8	17.6 ± 4.2	16.9 ± 5.4
Food insecurity ^{1,6}			
1 (less food insecure)	71 (94.7)	37 (92.5)	34 (97.1)
2	1 (1.3)	1 (2.5)	0 (0.0)
3	1 (1.3)	1 (2.5)	0 (0.0)
4	2 (2.7)	1 (2.5)	1 (2.9)
Household dietary diversity ^{1,7}	7.2 ± 1.6	6.7 ± 1.7	7.7 ± 1.4
Women			
Age, y	34.6 ± 8.6	35.8 ± 8.3	33.3 ± 9.0
18 to <25	13 (16.9)	5 (12.5)	8 (21.6)
25 to <35	24 (31.2)	10 (25.0)	14 (37.8)
35 to <50	40 (51.9)	25 (62.5)	15 (40.5)
Highest level of education			
No formal schooling	12 (15.6)	8 (20.0)	4 (10.8)
Grades 1–5	15 (19.5)	5 (12.5)	10 (27.0)
Grades 6–8	23 (29.9)	17 (42.5)	6 (16.2)
Grades 9–10	17 (22.1)	7 (17.5)	10 (27.0)

	Overall (n=77)	Sequence 1 (DFS-QFS) (n=40)	Sequence 2 (QFS-DFS) (n=37)
	Mean ± SD or n (%)	Mean ± SD or n (%)	Mean ± SD or n (%)
Grades 11–12	3 (3.9)	1 (2.5)	2 (5.4)
College or graduate degree	7 (9.1)	2 (5.0)	5 (13.5)
Marital status			
Currently married	70 (90.9)	37 (92.5)	33 (89.2)
Widowed, divorced, or separated	3 (3.9)	3 (7.5)	0 (0.0)
Never married	4 (5.2)	0 (0.0)	4 (10.8)
Household role			
Primary food preparer	64 (83.1)	33 (82.5)	31 (83.8)
Head of household	0 (0.0)	0 (0.0)	0 (0.0)
Both	10 (13.0)	7 (17.5)	3 (8.1)
Neither	3 (3.9)	0 (0.0)	3 (8.1)
Dietary preference			
Vegetarian	3 (3.9)	1 (2.5)	2 (5.4)
Non-vegetarian	74 (96.1)	39 (97.5)	35 (94.6)
Salt use at the table			
Very often (at almost every meal)	16 (20.8)	7 (17.5)	9 (24.3)
Often (about once a day)	22 (28.6)	14 (35.0)	8 (21.6)
Occasionally (less than once a day)	29 (37.7)	13 (32.5)	16 (43.2)
Almost never (less than once a week)	10 (13.0)	6 (15.0)	4 (10.8)
Tobacco use	2 (2.6)	0 (0.0)	2 (5.4)
Betel nut use	27 (35.1)	17 (42.5)	10 (27.0)

¹ n=2 missing

² n=1 missing

³ among n=69 households that reported using each type of salt

⁴ n=5 missing

⁵ Income eligibility for ration card in rural Andhra Pradesh

⁶ Assessed using household food insecurity access scale (66)

⁷ Assessed using household dietary diversity score (65), which ranges from 0 to 12 food groups consumed by household members at the home in the past 24 hours

Abbreviations: DFS, double-fortified salt (iron, iodine); QFS, quadruple-fortified salt (iron, iodine, folic acid, vitamin B12)

Table 2.

Triangle tests of salt interventions: Sensory discrimination among women 18–49 y

	n	n (%) correct	P-value¹
QFS vs. DFS	66		
Plain rice		26 (39.4)	0.18
Lemon rice		27 (40.9)	0.12
QFS vs. iodized salt	66		
Plain rice		17 (25.8)	0.88
Lemon rice		25 (37.9)	0.26
DFS vs. iodized salt	66		
Plain rice		23 (34.8)	0.45
Lemon rice		22 (33.3)	0.55

¹One-sided binomial test with continuity correction to test proportion >33.3%

Abbreviations: DFS, double-fortified salt (iron, iodine); QFS, quadruple-fortified salt (iron, iodine, folic acid, vitamin B12)

Table 3.

Triangle tests of salt intervention: Perceived sensory differences between food samples reported by women 18–49 y¹

		Plain rice, n (%)				Lemon rice, n (%)			
QFS vs. DFS		Overall	Correct (n=26)	Incorrect (n=40)	Overall	Correct (n=27)	Incorrect (n=39)		
Degree of difference									
Slight		49 (74.2)	19 (73.1)	30 (75.0)	43 (65.2)	23 (85.2)*	20 (51.3)*		
Moderate		15 (22.7)	6 (23.1)	9 (22.5)	20 (30.3)	4 (14.8)*	16 (41.0)*		
High		2 (3.0)	1 (3.8)	1 (2.5)	3 (4.5)	0 (0.0)*	3 (7.7)*		
Different taste		57 (86.4)	24 (92.3)	33 (82.5)	62 (93.9)	25 (92.6)	37 (94.9)		
Different odor		11 (16.7)	8 (30.8)*	3 (7.5)*	4 (6.1)	2 (7.4)	2 (5.1)		
Different texture		5 (7.6)	1 (3.8)	4 (10.0)	2 (3.0)	1 (3.7)	1 (2.6)		
Different color		4 (6.1)	2 (7.7)	2 (5.0)	4 (6.1)	2 (7.4)	2 (5.1)		
Reported guessing		1 (1.5)	0 (0.0)	1 (2.5)	0 (0.0)	0 (0.0)	0 (0.0)		
QFS vs. iodized salt		Overall	Correct (n=17)	Incorrect (n=49)	Overall	Correct (n=25)	Incorrect (n=41)		
Degree of difference									
Slight		50 (75.8)	15 (88.2)	35 (71.4)	43 (65.2)	18 (72.0)	25 (61.0)		
Moderate		16 (24.2)	2 (11.8)	14 (28.6)	23 (34.8)	7 (28.0)	16 (39.0)		
High		0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)		
Different taste		60 (90.9)	14 (82.4)	46 (93.9)	63 (95.5)	22 (88.0)*	41 (100.0)*		
Different odor		7 (10.6)	1 (5.9)	6 (12.2)	3 (4.5)	2 (8.0)	1 (2.4)		
Different texture		6 (9.1)	3 (17.6)	3 (6.1)	4 (6.1)	2 (8.0)	2 (4.9)		
Different color		4 (6.1)	1 (5.9)	3 (6.1)	3 (4.5)	2 (8.0)	1 (2.4)		
Reported guessing		1 (1.5)	1 (5.9)	0 (0.0)	1 (1.5)	1 (4.0)	0 (0.0)		
DFS vs. iodized salt		Overall	Correct (n=23)	Incorrect (n=43)	Overall ²	Correct (n=22)	Incorrect (n=44) ³		
Degree of difference									
Slight		52 (78.8)	20 (87.0)	32 (74.4)	39 (60.0)	13 (59.1)	26 (60.5)		
Moderate		14 (21.2)	3 (13.0)	11 (25.6)	24 (36.9)	9 (40.9)	15 (34.9)		
High		0 (0.0)	0 (0.0)	0 (0.0)	2 (3.1)	0 (0.0)	2 (4.7)		

Different taste	56 (84.8)	18 (78.3)	38 (88.4)	64 (97.0)	22 (100.0)	42 (95.5)
Different odor	11 (16.7)	7 (30.4) [*]	4 (9.3) [*]	1 (1.5)	0 (0.0)	1 (2.3)
Different texture	2 (3.0)	0 (0.0)	2 (4.7)	3 (4.5)	0 (0.0)	3 (6.8)
Different color	7 (10.6)	2 (8.7)	5 (11.6)	3 (4.5)	1 (4.5)	2 (4.5)
Reported guessing	2 (3.0)	0 (0.0)	2 (4.7)	0 (0.0)	0 (0.0)	0 (0.0)

¹Frequency of reported perceived differences (overall degree of difference, and whether participants reported perceived difference in specific sensory domains) between participants who selected the correct versus incorrect sample within each triangle test were assessed using logistic regression

²Degree of difference for DFS vs. iodized salt in lemon rice available from n=65 women

³Degree of difference for DFS vs. iodized salt in lemon rice available from n=43 women

^{*} p<0.05

Abbreviations: DFS, double-fortified salt (iron, iodine); QFS, quadruple-fortified salt (iron, iodine, folic acid, vitamin B12)

Table 4. Household randomized crossover trial: Weighted household use of intervention salt during a randomized crossover trial

	Salt type				Period				P-value ³	Iodized Salt (Week 2) ⁶				
	QFS		DFS		Week 1		Week 3			Salt type	Sequence	Period	n	Mean ± SD n (%)
	n	Mean ± SD n (%)	n	Mean ± SD n (%)	n	Mean ± SD n (%)	n	Mean ± SD n (%)						
Overall intervention salt use ^{1,3}														
Total, g	77	162.5 ± 167.6	77	181.7 ± 158.6	77	145.3 ± 145.2	77	198.9 ± 175.8	0.230	0.998	0.003	76	168.0 ± 154.7	
Per day, g	77	22.9 ± 24.2	77	26.2 ± 23.0	77	20.3 ± 20.6	77	28.8 ± 25.7	0.166	0.858	0.001	76	23.5 ± 21.9	
Per person ≥5 y per day, g	63	7.1 ± 7.3	72	7.8 ± 7.0	71	6.0 ± 6.4	64	9.1 ± 7.6	0.393	0.337	0.005	70	7.0 ± 7.0	
Per person ≥5 y per day, g ²	77	6.0 ± 7.1	77	7.5 ± 7.1	77	5.6 ± 6.3	77	7.8 ± 7.7	0.092	0.525	0.012	76	6.5 ± 6.9	
Households using intervention salt ^{1,3}														
Used ≥1g per person per day, n ⁴	63	45 (71.4)	72	54 (75.0)	71	47 (66.2)	64	52 (81.3)	0.701	0.364	0.028	70	52 (74.3)	
Used ≥5g per person per day, n ⁴	63	35 (55.6)	72	44 (61.1)	71	36 (50.7)	64	43 (67.2)	0.410	0.587	0.025	70	36 (51.4)	
Households using intervention salt ^{1,2,3}														
Used ≥1g per person per day, n ⁴	77	47 (61.0)	77	55 (71.4)	77	48 (62.3)	77	54 (70.1)	0.084	0.666	0.200	76	53 (69.7)	
Used ≥5g per person per day, n ⁴	77	37 (48.1)	77	45 (58.4)	77	37 (48.1)	77	45 (58.4)	0.089	0.805	0.089	76	36 (47.4)	
Intervention salt use (among households using ≥1 g per person per day) ^{3,5}														
Total, g	45	261.4 ± 139.8	54	251.0 ± 130.0	47	230.0 ± 115.2	52	279.0 ± 146.1	0.606	0.639	0.032	52	241.9 ± 131.8	
Per day, g	45	37.0 ± 20.8	54	36.3 ± 19.1	47	32.1 ± 16.7	52	40.7 ± 21.6	0.909	0.506	0.001	52	33.9 ± 18.8	
Per person ≥5 v per day, g	45	9.9 ± 6.8	54	10.4 ± 6.3	47	9.0 ± 5.8	52	11.1 ± 6.9	0.654	0.587	0.033	52	9.4 ± 6.6	

¹ n=1 weight for iodized salt removed due to implausible value (i.e., >500 g); as part of intention-to-treat analyses, weights were set to 0 for households missing salt weight data

² For a given week in which the number of individuals who consumed meals at the household was missing, salt use per person per day was calculated using the median value of the number of individuals from the other study time points

³ Data were analyzed by a mixed model that included household as random effect and salt type (QFS vs. DFS), period (week 1 vs. week 3), and randomization sequence (sequence 1 vs. 2) as a fixed effect

⁴ Dichotomous variables were assessed using binomial regression; Poisson distribution was used when models failed to converge

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⁵Sensitivity analyses for salt use (continuous) were conducted among households that used ≥ 1 g per person ≥ 5 y per day

⁶Data for iodized salt (i.e., week 2) is presented for reference and was not included in models

Abbreviations: DFS, double-fortified salt (iron, iodine); QFS, quadruple-fortified salt (iron, iodine, folic acid, vitamin B₁₂)

Table 5.

Individual hedonic ratings of women 18–49 y

	Salt type				Period				P-value ¹			Iodized Salt (Week 2) ²	
	QFS		DFS		Week 1		Week 3						
	n	Mean ± SD	n	Mean ± SD	n	Mean ± SD	n	Mean ± SD	Salt type	Sequence	Period	n	Mean ± SD
Color	47	7.7 ± 0.8	57	7.5 ± 1.3	51	7.2 ± 1.3	53	7.9 ± 0.7	0.534	0.223	<0.001	56	7.8 ± 0.7
Odor	47	7.0 ± 1.0	57	7.1 ± 1.1	51	6.7 ± 1.2	53	7.4 ± 0.8	0.611	0.906	<0.001	56	7.3 ± 0.9
Taste	46	7.7 ± 0.9	57	7.6 ± 1.1	51	7.4 ± 1.0	52	7.9 ± 1.0	0.417	0.970	0.028	56	7.6 ± 1.1
Texture	46	7.0 ± 1.1	57	6.8 ± 1.2	51	6.7 ± 1.2	52	7.0 ± 1.1	0.246	0.057	0.070	56	6.9 ± 1.1
Overall	46	7.8 ± 0.7	56	7.7 ± 1.2	51	7.5 ± 1.3	51	8.0 ± 0.5	0.679	0.179	0.017	56	7.8 ± 0.7

¹Data were analyzed using a mixed model that included household as random effect and salt type (QFS vs. DFS), period (week 1 vs. week 3), and randomization sequence (sequence 1 vs. 2) as fixed effect

²Data for iodized salt (i.e., week 2) is presented for reference and was not included in models

Abbreviations: DFS, double-fortified salt (iron, iodine); QFS, quadruple-fortified salt (iron, iodine, folic acid, vitamin B12); SD, standard deviation