Effects of salt fortified with iron and iodine on the haemoglobin levels and productivity of tea pickers

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Abstract

*To determine if double-fortified salt improved the haemoglobin levels and productivity of tea pickers, a double-blind, randomized, placebo-controlled trial was conducted on 793 tea pickers. The subjects in the experimental households (*n *= 385) received salt fortified with iron and iodine, and the subjects in the control households (*n *= 408) received common unfortified salt. Fingerprick blood analysis for haemoglobin by the cyanmethaemoglobin method was performed three times during a period of one year. The productivity data were also analysed for 450 tea pickers. At the end of the year, their average haemoglobin level had increased from 8.9 to 10.2 g/dl and their corresponding picking average had increased from 24.8 kg to 26.2 kg, which could increase annual tea production by 330 tonnes.*

Introduction

It is well known that anaemia affects the productivity of workers [1–5] and that productivity improves when anaemia is reduced. In fact, anaemia is associated with reduced production of women workers even in less physically strenuous tasks, as seen in jute factory workers [6]. Tea estates provide a valuable opportunity to measure the productivity of the workers, because the work done by an individual is quantifiable as kilograms of tea leaves picked per day. These results are similar to those of Edgerton et al. [7], who found a decrease in work performance capacity in iron-deficient male tea pickers with anaemia. The present study provides additional evidence for the link between anaemia and the productivity of plantation workers.

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Development

Sundar Chemicals developed and introduced Nutrisalt, a common cooking salt fortified with both iron and iodine to alleviate iron and iodine deficiencies in developing third world countries. Earlier this company was a pioneer in developing and marketing iron-fortified salt in India. Several problems had to be overcome during the development of both iron-fortified salt and double-fortified salt. Normally iron compounds that are used in fortification tend to discolour food during cooking. It took several years of research to develop a suitable iron product that would not discolour the salt during the process of fortification or discolour any foods during cooking, and that would be stable on storage and bioavailable. Stabilizing chemicals were used that enhanced the bioabsorption of iron, not only from the salt, but also from the food consumed.

In the development of double-fortified salt, there were problems related to the stability of iodine. It is well known that iodine is stable in an alkaline pH, whereas iron requires an acidic pH. Intensive research led to the development of a product in which both iron and iodine were stable for more than a year. There was no development of colour when it was used in cooking, nor was there any change in the taste of the food.

Study design

The study was conducted jointly by Sundar Chemicals, Parry Agro Group, and United Planters Association of South India. The CWS tea estate of the Parry Agro Group, in the hilly region of Valparai in South India, was chosen as the area for the study. On the basis of the terrain, the tea estate is divided into lower Sheikalmudi and Upper Sheikalmudi regions. Both regions were considered for the trial. The study was designed by Dr. S. Rajagopalan. Dr. P. Shankar of Parry Agro, the director of the hospital attached to the tea estate, acted as the project leader and took responsibility for conducting the trial. Ms. Savithri of the United

Planters Association of South India acted as a project coordinator and helped to create nutritional awareness in the labour community.

This tea estate was chosen for the study for several reasons. It is isolated and far from the city in the remote interior hilly region. Therefore easy access to salt other than the fortified salt is not possible. Such a closed community can be easily monitored. Blood for analysis can be taken from the workers when they report for work in the tea plantation. Since the workers are paid according to the quantity of tea leaves they pick, their productivity can be measured, and the effect on productivity of a reduction in anaemia can be quantified.

The workers live in rows of houses called lines. Each line is a building containing eight to ten households. A number of such lines constitutes a cluster. There are several clusters spread throughout the plantation. By using a map of the entire plantation, the area was divided into 20 clusters. Care was taken to see that all the clusters had approximately the same number of lines and houses to insure a uniform sample size in every cluster. With the use of a table of random numbers, every cluster was assigned to either an experimental or a control cluster. The study was a double-blind, randomized, placebo-controlled trial. Only the project leader knew which were the experimental and which were the control households.

There were 2,659 people living in 671 houses on the tea estate, 1,327 people in the experimental area and 1,332 in the control area. These numbers include the entire population, adults and children. Although 2,659 people consumed Nutrisalt, blood analysis was done on only 1,320 adult labourers. Of these 1,320, 1,096 were permanent workers and the rest were casual workers. Only 793 of the 1,096 permanent labourers came for all three rounds of haemoglobin analysis, and only this sample was considered for final statistical analysis. Of the 793 labourers, 408 were in the control group and 385 were in the experimental group.

Baseline studies and education before the beginning of the experiment

The plantation was equipped with good hospital facilities on the premises. CWS Parry Agro Company keeps detailed morbidity reports on all their workers. Baseline studies included a study of the nutritional pattern of the workers. The quantity of vegetables, dhal (lentils), and rice consumed by the families on a weekly basis was monitored to give information on dietary intake. From the hospital records, it was noted that amoebic and hookworm infestations were rampant and dietary intakes of iron and protein were low. All these factors contributed to the anaemia prevailing in the area.

The experimental salt was in powdered form, but the plantation workers were used to crystal salt. Before the start of the trial, the project coordinator gave talks and cooking demonstrations on how to use the powdered salt. The population was instructed that iron- and iodine-fortified experimental salt had nutritional benefits and that they could use it as they used crystal salt. Through cooking demonstrations, they observed that the fortified salt did not change the colour, taste, or appearance of the food. These demonstrations helped them to overcome their fears about the salt, and they enthusiastically began using it.

For the first three months, unfortified powdered salt was supplied to the entire population to get them accustomed to using powdered instead of crystal salt. After the powdered salt had been accepted by the population, the unfortified salt in the experimental areas was replaced with double-fortified salt.

Before the start of the programme, the first fingerprick blood samples were collected and analysed for haemoglobin. Deworming and treatment with iron and folic acid tablets were also stopped. After three months, when the population had become accustomed to the powdered salt, another fingerprick blood sample for haemoglobin analysis was taken.

Comparison of haemoglobin levels in these two samples showed that there was a marked increase in anaemia in those three months. It was believed that this marked increase in anaemia was caused by stopping deworming. It was therefore decided to deworm half the population in both the experimental and control areas and then administer the iron- and iodine-fortified salt in the experimental area and unfortified salt in the control area. This would eliminate the anaemia caused by worm infestation and facilitate determining whether further administration of iron- and iodine-fortified would help to reduce anaemia.

Blood collection, determination of haemoglobin, and quality control

Fingerprick blood samples were taken for haemoglobin analysis at the beginning, middle, and end of the study. Each permanent worker on the CWS estate is given a provident fund number. When the workers assembled at the fields to pick tea, the fingerprick blood samples were taken, accurately measured in a 0.02-ml (20-μl) micro pipette, and transferred immediately into vials containing 5 ml of Drabkins solution labeled with the PF number of the worker. The vials were packed in ice and immediately taken to the laboratory for analysis.

Haemoglobin was determined by the cyanmethaemoglobin method using Drabkins solution for colour development. The developed colour was read on a photoelectric colourimeter. The optical density was compared with the optical density of the standard. To avoid errors in preparation of the standard, a commercial standard was used.

Validation of the blood samples

For 10% of the population, blood samples were collected again soon after the first prick and transferred into separate vials. Each vial was then independently analysed by two different technicians.

Production and coding of double-fortified salt

The double-fortified salt was produced by Sundar Chemicals and packed in 1-kg bags. Fifty of the 1-kg bags were placed in a larger bag. A sheet containing the code for iron- and iodine-fortified salt was placed in the bag, and the bag was stitched. The code was also printed on the outside. Unfortified salt was similarly packaged and identified by code. The bags were then despatched to the project leader, Dr. P. Shankar, who was the only one who knew the codes.

Salt distribution

A register was maintained from the beginning of the trial to determine the quantity of salt required by the households. The project leader, after decoding the bags, despatched the appropriate quantity of salt needed for the trials to the project workers, who delivered the required quantity of the salt to the individual households. A detailed register contained data on the quantity of salt delivered during each visit, and their requirement of salt was recorded. The project workers did not know whether the salt they were distributing was iron- and iodine-fortified or unfortified.

Checks to ensure that only Nutrisalt was used

Project workers made periodic surprise visits to the houses of the workers and collected salt samples from their kitchens for analysis. These checks proved that the population was using only Nutrisalt.

Stability of iron and iodine in Nutrisalt

Sundar Chemicals retained control samples of every batch of salt. The iron and iodine contents were periodically monitored in their laboratory. Samples collected from the kitchens of the workers were also sent to the Sundar Chemicals laboratory in Madras for determination of the stability of the micronutrients at the end user level. Sundar Chemicals had previously noted that both iron and iodine were stable in these samples for more than a year.

Measurement of productivity

Productivity data were gathered for about 450 permanent employees whose blood was analysed for haemoglobin. The Parry Agro group maintains detailed records of the tea leaves picked by an individual each day. At the end of every month, data are transferred into another register that contains data such as the total quantity of tea leaves picked by an individual as well as the total number of days worked for the entire month. The total quantity of leaves picked by an individual for a month divided by the total number of days worked gives the average daily quantity of tea leaves picked by the individual. Two-criteria analysis of variance was performed with the productivity data for the first six months and again for the second six months. The picking average for the first six months was averaged for every individual, and these numbers were subjected to two-criteria analysis of variance. The data for the second six months were analysed in the same way. The two criteria for analysis of variance were experimental versus control group and deworming versus no deworming. Half the subjects in each group, experimental and control, were dewormed. The scheme and design of the analysis are represented in tables 1 and 2.

TABLE 1. Two-criterion analysis of variance of picking average for first six months

Dewormed	Experimental (fortified salt)	Control (unfortified salt)
No	N_1 (no. of samples in this block) = 118 M_1 (mean of samples in this block) = 21.79 A_1 (sum of samples in this block) = 2,571.27	N_2 (no. of samples in this block) = 114 M_2 (mean of samples in this block) = 21.80 A_2 (sum of samples in this block) = 2,485.05
Yes	N_3 (no. of samples in this block) = 103 M_3 (mean of samples in this block) = 24.84 B_1 (sum of samples in this block) = 2,558.22	N_4 (no. of samples in this block) = 119 M_4 (mean of samples in this block) = 24.69 B_2 (sum of samples in this block) = 2,937.80

M_a (mean for row 1 [not dewormed]) = $(A_1 + A_2)/(N_1 + N_2)$ = 21.79.
M_b (mean for row 2 [dewormed]) = $(B_1 + B_2)/(N_3 + N_4)$ = 25.76.
M_{A1B1} (mean for experimental column) = $(A_1 + B_1)/(N_1 + N_3)$ = 23.21.
M_{A2B2} (mean for control column) = $(A_2 + B_2)/(N_2 + N_4)$ = 23.27.
Overall mean = $(A_1 + A_2 + B_1 + B_2)/(N_1 + N_2 + N_3 + N_4)$ = 23.24.

TABLE 2. Two-criterion analysis of variance of picking average for second six months

Dewormed	Experimental (fortified salt)	Control (unfortified salt)
No	N_1 (no. of samples in this block) = 114 M_1 (mean of samples in this block) = 23.29 A_1 (sum of samples in this block) = 2,655.18	N_2 (no. of samples in this block) = 112 M_2 (mean of samples in this block) = 24.16 A_2 (sum of samples in this block) = 2,706.18
Yes	N_3 (no. of samples in this block) = 101 M_3 (mean of samples in this block) = 26.15 B_1 (sum of samples in this block) = 2,641.35	N_4 (no. of samples in this block) = 117 M_4 (mean of samples in this block) = 25.06 B_2 (sum of samples in this block) = 2,931.72

M_a (mean for row 1 [not dewormed]) = $(A_1 + A_2)/(N_1 + N_2)$ = 23.72.
M_b (mean for row 2 [dewormed]) = $(B_1 + B_2)/(N_3 + N_4)$ = 25.56.
M_{A1B1} (mean for experimental column) = $(A_1 + B_1)/(N_1 + N_3)$ = 24.64.
M_{A2B2} (mean for control column) = $(A_2 + B_2)/(N_2 + N_4)$ = 24.62.
Overall mean = $(A_1 + A_2 + B_1 + B_2)/(N_1 + N_2 + N_3 + N_4)$ = 24.63.

Results

Haemoglobin analysis

At the beginning of the study, the mean haemoglobin level of the control group was higher than that of the experimental group that received the iron- and iodine-fortified salt. However, at the end of the trial, the mean haemoglobin level of the experimental group had increased significantly (table 3). Table 4 shows the haemoglobin levels according to age and sex at the end of the study. For men in the experimental group, the mean haemoglobin level was higher than that of the control group among those aged 18 to 30 and over 45. For women in the experimental group, the mean haemoglobin level was higher than that of the control group among those aged 18 to 30 and 31 to 45.

The average increase in the haemoglobin level in the experimental group was 1.27 g/dl, 65% greater than the average increase of 0.77 g/dl in the control group (Z = .77; $p < .05$). At the end of the trial, the increase in the mean haemoglobin level in the dewormed experimental group compared with that in the non-dewormed group was nearly three times (0.31 g/dl) greater than

TABLE 3. Mean ± SD haemoglobin levels (g/dl)

Sex of subjects and stage of study	Experimental (fortified salt)	Control	*p*
Male	(*n* = 155)	(*n* = 158)	NS[a] (Z = 1.08)
Baseline	9.57 ± 0.140	9.71 ± 0.137	
Middle	9.63 ± 0.135	9.75 ± 0.120	
End	10.42 ± 0.153	10.30 ± 0.146	
Female	(*n* = 230)	(*n* = 250)	< .05 (Z = 2.55)
Baseline	8.48 ± 0.132	8.92 ± 0.159	
Middle	8.61 ± 0.099	8.68 ± 0.093	
End	10.031 ± 0.134	9.75 ± 0.132	

a. Not significant.

TABLE 4. Haemoglobin levels (mean ± SD g/dl) according to sex and age group at the end of the study

	Experimental (fortified salt)		Control			
Sex and age group (yr)	*n*	Haemoglobin	*n*	Haemoglobin	Z	*p*
Male						
18–30	46	10.20 ± 0.263	44[a]	9.96 ± 0.271	1.15	NS[b]
31–45	81	10.58 ± 0.222	83	10.59 ± 0.188	0.11	NS
> 45	28	10.33 ± 0.344	30	9.98 ± 0.415	1.34	NS
Female						
18–30	84[a]	9.72 ± 0.207	92	9.50 ± 0.208	1.43	NS
31–45	116	10.27 ± 0.199	95	9.78 ± 0.203	3.53	<.05
> 45	29	10.02 ± 0.345	63	10.27 ± 0.286	1.09	NS

a. Included one subject less than 18 years of age.
b. Not significant.

the increase in haemoglobin in the control group (0.08 g/dl). Deworming further enhanced the effect of double fortification, as seen in table 5.

The reduction in severe anaemia (defined as haemoglobin level less than 8 g/dl) was greater in the experimental group than in the control group among both dewormed and non-dewormed subjects. The increase in the proportion of non-anaemic subjects in the dewormed group was more than twice the increase in the non-dewormed experimental group (table 6).

Productivity data

The interaction effect between deworming and iron supplementation on the picking average was not seen in the first six months of the trial, whereas the deworming and non-deworming component gave a value at 95% (table 7). In the second six months, the interaction of iron supplementation with deworming had significant effects on the picking average at a level of 95% (table 8). This may mean that it takes about six months for the

TABLE 5. Combined effect of deworming and of salt fortified with iodine and iron on mean haemoglobin levels (g/dl)

	Control				Experimental (fortified salt)				
Dewormed	*n*	Baseline	End	Change	*n*	Baseline	End	Change	*p*
Yes	198	9.14	10.04	0.90	185	8.87	10.35	1.48	<.05
No	210	9.30	9.95	0.65	200	8.96	10.04	1.08	NS[a]
Combined groups	408	9.22	9.99	0.77	385	8.92	10.19	1.27	<.05

a. Not significant.

TABLE 6. Combined effect of deworming and of salt fortified with iodine and iron on changes in incidence (%) of anaemia

	Control		Experimental (fortified salt)	
Anaemia status[a]	Dewormed	Not dewormed	Dewormed	Not dewormed
Severe anaemia	–15.64	–9.04	–22.5	–15.50
No anaemia	+7.57	+5.72	+18.37	+9.00

a. Hemoglobin concentrations: severe anaemia, <8 g/dl; no anaemia, >12 g/dl.

TABLE 7. Analysis of variance of productivity: picking averages for the first six months[a]

Source of variation	SS	df	MSS	*F* ratio	*p*
Variable: dewormed vs not dewormed	995.54	1	995.54	68.23	.05
Variable: fortified salt vs control	0.46	1	0.46	0.0315	NS
Variable: interaction of fortified salt and deworming	2.69	1	2.69	0.1845	NS
Error	6,566.54	450	14.59		
Total variation	7,565.23	453	16.70		

a. SS, Sum of squares; df, degrees of freedom; MSS, mean square; NS, not significant.

TABLE 8. Analysis of variance of productivity: picking averages for the second six months[a]

Source of variation	SS	df	MSS	*F* ratio	*p*
Variable: dewormed vs not dewormed	376.35	1	376.35	14.05	<.05
Variable: fortified salt vs control	0.0262	1	0.026	0.00098	NS
Variable: interaction of fortified salt and deworming	107.54	1	107.54	4.0155	<.05
Error	11,784.23	440	26.7823		
Total variation	12,268.14	443	27.69		

a. SS, Sum of squares; df, degrees of freedom; MSS, mean square; NS, not significant.

increase in haemoglobin levels to translate into an increase in the picking average. In any community with a high incidence of worm infestation, iron supplementation at the level of daily requirements may not have any effect, because iron absorption is limited when parasitic worm infestation is high. For the purpose of the experiment, we allowed deworming in 50% of those in both the experimental and control groups. This also gave us an insight into the interaction effect of iron supplementation with deworming on the picking average, which we would have missed otherwise.

The impact of iron supplementation on the dewormed sample and its effect on the picking average in both periods, taking into account the *t* ratio between the two mean values, are shown in tables 9 and 10.

At the end of the second six months, the mean picking average of the experimental dewormed group was significantly higher than that of the control dewormed group. The picking average for the first six months did not significantly differ in the experimental and control groups. This establishes the significant impact of iron supplementation by the use of double-fortified salt on the productivity of tea pickers. These results are similar to those of other studies [8] and of the Chinese studies [9] in which iron supplementation enabled cotton mill workers in Beijing to do the same work at a lower energy expenditure when anaemia was alleviated.

Effect of reducing anaemia on absenteeism

The number of days worked by the whole group for the one-year control period before the start of the trial was 96,034 person-days. The same group worked for 97,602 person-days during the one-year experimental period. This was an increase of 1,568 person-days compared with the previous year. The tea pickers also reported a feeling of well-being and were less irritable and less fatigued at the end of the one-year period during which they consumed Nutrisalt. This is probably due to the improvement in their haemoglobin levels. The increase in the number of days worked during the trial period also reflects the decrease in absenteeism due to fatigue. These results are similar to those of the Sri Lankan study on tea pickers, in which the quantity of tea leaves picked increased when anaemia was alleviated [10].

Cost-benefit ratio

Each person consumes 10 g of salt per day. Thus 450 people would consume 4.5 kg of salt per day or 1,620 kg per year. At the rate of Rs. 4.50 per kilogram, the cost of double-fortified salt for 450 people would be Rs. 7,290 per year (US$215).

From the statistical analysis, it is seen that during the second six months of the trial, the experimental dewormed group picked 1.1 kg more tea leaves per day than the control dewormed group (26.2 and 25.1 kg, respectively). If these data can be extrapolated to 1,000 workers, these 1,000 workers could pick 1,000 × 1.1 kg more tea leaves per day (27.5 tonnes more per month and 330 more tonnes per year). Therefore, for an expenditure of Rs. 7,290 per year (US $215), an additional 300 tonnes of extra tea leaves could be picked. This demonstrates that a small sum of money spent in eliminating micronutrient deficiencies would increase productivity.

Conclusions

Nutrisalt is a double-fortified salt enriched with iron (1,000 ppm) and iodine (30 ppm) in which the two micronutrients are stable for more than a year. There was no change in the colour, taste, or smell of the food when Nutrisalt was used in cooking. Statistical analysis

TABLE 9. Dewormed sample: first six months picking average

Value	Control	Experimental (fortified salt)
Mean	24.68739 kg	24.83706 kg
Variance	12.50529	14.07773
Observations	119	103
Hypothesized mean difference	0	
Degrees of freedom	211	
t statistic	–0.304376	
$p\ (T \leq t)$ one-tail	0.380571	
t critical one-tail	1.652106	
$p\ (T \leq t)$ two-tail	0.761141	
t critical two-tail	1.971271	

Difference in picking average not significant ($p = < .05$) by *t* test for two samples assuming unequal variances.

TABLE 10. Dewormed sample: second six months picking average

Value	Control	Experimental (fortified salt)
Mean	26.15198 kg	25.05741 kg
Variance	14.02874	15.32912
Observations	101	117
Hypothesized mean difference	0	
Degrees of freedom	214	
t statistic	2.106832	
$p\ (T < = t)$ one-tail	.018148	
t critical one-tail	1.652006	
$p\ (T < = t)$ two-tail	.036297	
t critical two-tail	1.971111	

Difference in picking average significant ($p = < .05$) by *t* test for two samples assuming unequal variances.

using the Z test showed that at the end of the trial, the average haemoglobin level in the group receiving the iron- and iodine-fortified salt was significantly higher than that of the control group for both men and women. The mean increase in haemoglobin levels in the experimental group compared with the controls was slightly higher in women. The reduction in severe anaemia (haemoglobin < 8 g/dl) was 53% greater in the experimental group than in the control group. The increase in the proportion of non-anaemic subjects in the dewormed group was more than twice that in the non-dewormed experimental group. At the end of one year, the average haemoglobin level in the experimental group had increased from 8.9 to 10.2 g/dl and their tea- picking yield had increased from 24.8 kg to 26.2 kg, equivalent to an annual 330-tonne increase in tea production for the group receiving the iron- and iodine-fortified salt. Double-fortified salt was well accepted by the community and would be purchased if marketed.

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