Can increased vegetable consumption improve iron status?

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Abstract

Theoretically, vegetable consumption could improve iron status. First, vegetables contain iron. Second, when the provitamin A carotenoids in vegetables improve vitamin A status, the result could be increased iron levels. Most studies on vegetable consumption have focused on improvements in vitamin A status, and only very few have addressed iron status. From a review of the literature and a recent study in Indonesia, we conclude that the data on the effectiveness of vegetables to improve the levels of both nutrients are inconclusive. The bioavailability of both iron and provitamin A carotenoids might be lower than expected. It is necessary to conduct other intervention studies using plant foods, animal foods, and fortified foods. In the meantime, other strategies that have been proved to reduce iron and vitamin A deficiencies should continue.

Background

Food-based approaches to combat deficiencies of micronutrients such as iron and vitamin A deserve great attention, because they are likely to be sustainable in the long term, and the intake of other nutrients will increase simultaneously. Few studies, however, have evaluated the effectiveness of vegetables and fruits to combat iron and vitamin A deficiencies.

Most studies with vegetables have focused primarily on vitamin A status. A well-controlled study showed an increase in serum retinol levels after subjects ate red sweet potato and dark green leafy vegetables [1]. The increase in serum β-carotene after subjects consumed carrots was only 14% to 20% of the increment after an equal dose of purified β-carotene [2, 3], although it was expected to be about 33%. Other investigators failed to report any improvement of serum β-carotene levels after feeding the subjects carrots [4].

According to our recent literature review, evidence that eating fruits and vegetables may improve vitamin A status is inconclusive [5]. Because vegetables contain iron, increased consumption of vegetables would be expected to improve iron status, although the increase might be small because the bioavailability of iron in these foods is poor [6]. It is also possible that if vitamin A status improves after eating vegetables, iron status will do so as well, because improving the vitamin A status of anaemic subjects also increases haemoglobin levels [7, 8]. Ivy-gourd (1.1 mg β-carotene/day) given for a relatively short period of two weeks did not improve haematocrit level [9], whereas supplements of vegetables and purified β-carotene (1.2 mg/day) given for three months [10], and papaya (1.2 mg β-carotene/day), amaranth (1.2 mg β-carotene/day), or retinol (300 g/day) given for two months [11], improved haemoglobin concentrations. Another study (Muhilal and Karyadi, personal communication) found no improvement in concentrations of serum retinol and haemoglobin after feeding vegetables (1.9 mg β-carotene/day) for 75 days, but salt fortified with retinol (300 RE/day) improved serum concentrations of retinol and haemoglobin.

Because the findings on the role of vegetables in improving vitamin A status are inconclusive, and only very few studies have investigated their effects on iron status, more research is urgently needed to evaluate dietary approaches, especially those using vegetables, for combating iron and vitamin A deficiencies.

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Recent study in Indonesia

We recently investigated whether an additional daily portion of local vegetables can improve iron and vitamin A status in anaemic breastfeeding women in a rural area in the Bogor district, west Java [12]. The intervention lasted 12 weeks. One group received stir-fried vegetables, and a second group received a wafer enriched with iron, β-carotene, folic acid, and vitamin C, to examine the effect of a similar amount of micronutrients in a matrix with better bioavailability. A third group received a non-enriched wafer to control for effects of additional energy intake. Each of the 191 women had a breastfed child age 3 to 17 months, a baseline haematocrit below 38%, and a haemoglobin concentration below 130 g/L as measured by the cyanmethaemoglobin method.*

Assignment to the vegetable or wafer groups was done by village, which was justified by the larger intra-village than inter-village differences. The vegetable supplements contained 100 to 150 g of cassava leaves (*Manihot utilissima*), water spinach (*Ipomoea aquatica*), spinach (*Amaranthus viridis*), or carrots (*Daucus carota*). The wafers were wrapped in blue or red foil and distributed double-blind. The compositions of the prepared vegetable supplements and the enriched wafers as analysed were as follows: all-trans-β-carotene: vegetables 3.5 mg, wafers 3.5 mg; iron: vegetables 5.2 mg, wafers 4.8 mg; folic acid: vegetables 130 μg, wafers 100 μg; and vitamin C: vegetables 11 mg, wafers 22 mg. The control wafer contained less than 10% of these micronutrients. The fat content of the vegetables was 7.8 g, that of the wafers 4.5 g.

Follow-up data were obtained for 175 women. None of them suffered from clinical infections, but almost all had one or more parasitic infestations. Compliance was ensured by observing the women consume the supplement. Replacement of the participants' own vegetable dishes was avoided by bringing the supplement in the early morning, when the women would not usually eat vegetables. That the vegetables really were a supplement was ascertained by the following observations:

1. The intake of macronutrients, iron, and vitamin A–rich foods, calculated from 24-hour recall questionnaires, remained the same before and during the intervention in all groups.
2. The weight loss was similar in the three groups.
3. The treatment effect was the same in subjects who lost weight as in those who gained weight.

The iron status values, haematocrit, zinc protoporphyrin, and serum concentrations of ferritin and transferritin receptor measured at baseline, and the haemoglobin concentration at three weeks, did not differ among the groups, except for a slightly higher concentration of serum transferrin receptor in the vegetable group compared with the control wafer group. Between the third week and follow-up, the haemoglobin concentrations increased in all groups (baseline mean 109 g/L; 95% confidence interval (95% CI) of the increment 7 to 10 g/L; $n = 175$). Between baseline and follow-up, the serum transferrin receptor concentration decreased in all groups (baseline median 4.25 mg/L; 95% CI of the decrement -0.6 to -0.3 mg/L; $n = 174$). The haematocrit increased in the vegetable and enriched wafer groups. The changes were not significant in all groups, but none of the changes were different among the treatment groups (analysis of covariance). All improvements in iron status seemed to be due to regression to the mean, because all subjects were selected on the basis of a low haemoglobin level, and to the recovery of blood loss from pregnancy and delivery.

The baseline concentrations of retinol in serum and breastmilk and of β-carotene in serum did not differ among the groups. The retinol concentrations in serum and breastmilk of the enriched wafer group showed large increments, one-third and two-thirds, respectively. These were significantly different from the changes in the control wafer group and the vegetable group. Both concentrations did not change in the vegetable group, and breastmilk retinol showed a marginal increase in the control wafer group. The serum β-carotene concentration increased almost fourfold in the enriched wafer group. It increased slightly but without physiological relevance in the vegetable group, and it remained unchanged in the control wafer group.

In summary, improvements in iron status were similar in the three treatment groups, but a physiologically meaningful change of vitamin A status occurred only in the enriched wafer group. It seems that the contents of iron and vitamin C of the vegetables (5.2 and 11.4 mg, respectively) and of the enriched wafer (4.8 and 21.5 mg, respectively) were too small to improve iron status. The bioavailability of iron in vegetables is known to be poor [6]. The enriched wafer contained carbonyl iron, the bioavailability of which seems comparable with that of ferrous sulphate [13] but might be reduced by incorporation in foods [14].

*Because of problems with the Hemocue device at the baseline haemoglobin measurement, we were unable to comply strictly with our enrollment criterion for haemoglobin of 120 g/L. When the Hemocue cuvettes were used within two days after breaking the seal of the container, the results were comparable to those of the cyanmethaemoglobin method. However, when the cuvettes were used longer after opening the container, the results were erratic. This might have been due to the warm and especially humid climate in the study area. During the third week of the intervention, therefore, an additional blood sample was taken to measure haemoglobin using the cyanmethaemoglobin method.

The improvement of vitamin A status of the enriched wafer group seems not to have improved iron status. However, for the women with a baseline serum retinol level below 0.70 μmol/L, the increase in haematocrit was significantly greater ($p < .05$) in the enriched wafer group (95% CI 0.01 to 0.02, $n = 20$), compared with the control wafer group (95% CI −0.01 to 0.01, $n = 24$), or the vegetable group (95% CI 0.00 to 0.01, $n = 19$). Increases in haemoglobin levels showed a similar but not significant trend, whereas other iron status values showed no differences among the groups.

The difference in change of iron status between the group that improved in vitamin A status and those that did not was smaller than that observed in other studies. A possible explanation is that higher doses of vitamin A were given in the other studies—a single dose of 110,000 RE [7] or a daily dose of 2,400 RE for eight weeks [8]—which might have caused a change in iron status within a shorter period of time. The very small variation in serum β-carotene response in the vegetable group suggests that the bioavailability of β-carotene was equally poor for all subjects.

Thus, the main reason for the finding that iron status was not improved by vegetables seems to be that the iron has poor bioavailability and the amount provided was small, whereas the main reason for the finding that vitamin A status was not improved by vegetables seems to be that it was too difficult to break down the matrix in which the carotenoids are captured in the leaves and the complex that they form with proteins for photosynthesis. The difficulty in freeing β-carotene from its matrix might have been aggravated by parasitic infestations.

Conclusion

Because only very few food-intervention studies have looked at iron status, and because the available results are contradictory, no firm conclusions can be drawn as to whether or not vegetables can improve iron status. It is necessary to conduct similar intervention studies with foods of both plant and animal origin and with fortified foods, and to investigate ways to improve the bioavailability of nutrients. Alternative approaches, such as food fortification and promotion of animal foods rich in haem iron and retinol, must be considered. In the meantime, the use of other strategies that have proved to be effective to reduce iron and vitamin A deficiencies should continue.

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