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OPTIMIZING MICRONUTRIENT INTAKE OF LACTATING WOMEN THROUGH INCREASED WILD EDIBLE PLANT CONSUMPTION IN KWAZULU-NATAL, SOUTH AFRICA

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ABSTRACT

Micronutrient consumption in many developing countries is insufficient to meet the needs of numerous individuals, resulting in a negative impact on health. Increasing consumption of wild edible plants, which are micronutrient rich, easy to grow, and culturally familiar, has been recommended to combat these deficiencies, but there is a gap in knowledge on which types of plants should be eaten or in what quantity. The objective of this project was to determine the optimal blend of South African wild edible plants needed to fill gaps between typical micronutrient consumption of lactating women in KwaZulu-Natal, South Africa, and estimated requirements. This was done by creating optimization models using linear programming. Components of these models included identifying gaps between current micronutrient intake measured in a sample of lactating women and Estimated Average Requirements (EAR) and the creation of composite nutrient profiles for groups of wild edible plants available in KwaZulu-Natal. Models calculated the optimum amounts of wild edible plants that would need to be consumed in addition to the current diet to meet micronutrient recommendations and the amounts needed if half the additional calories consumed would replace an equivalent number of calories of maize meal. A combination of 250g leafy vegetables and 349g fruit, replacing 54g of maize meal, was determined to be the best model. This mixture met the micronutrient needs of 50% of lactating women and added only 192 calories to the diet. This data can provide policy makers with the information necessary to formulate effective nutritional interventions. The high level of recommended change, however, also highlights the need to employ multiple approaches to achieving improved nutrition. Additional information is needed on the availability and nutritional values of wild edible plants in South Africa. Despite these limitations, it is clear that a reasonable increase in wild edible plant consumption can have a tremendous positive impact on micronutrient consumption of lactating women in KwaZulu-Natal, South Africa.

Key words: wild edible plants, diet, lactation

INTRODUCTION

South Africa, like many developing countries, suffers from high rates of infectious and chronic diseases, both of which are linked to poor nutrition [1]. Insufficient intake of nutrients, particularly protein, vitamins A, C, E, and B-complex, iron, zinc, and selenium, negatively impact the immune system, increasing the frequency and severity of infectious diseases [2]. At the same time, diets high in carbohydrates and saturated fat and low in fresh fruits and vegetables, along with risk factors such as low physical activity, are bringing about high rates of obesity and associated chronic diseases [3]. Interventions are needed to help correct some of the nutritional inadequacies and improve the health of vulnerable groups in the population.

The nutritional status of lactating women is of particular importance. During lactation, the maternal requirement for protein, vitamins A, B_6, C, riboflavin, and trace elements zinc and iodine are between 40-90% higher than pre-pregnancy and requirements for thiamine, niacin, folate, vitamin E, and selenium are about 25% higher [4]. In addition to affecting her own wellbeing, a mother's nutritional status also affects the concentrations of certain micronutrients in breast milk, notably the B vitamins, vitamin A, and iodine, which can have long term impacts on her child's health [5].

Adequate consumption of fruits and vegetables is known to improve nutritional status, decrease the risk of certain chronic diseases, and improve immune response. Consumption of fruits and vegetables in South Africa is very low, most likely due to limited availability and widespread poverty [6]. The government of South Africa, in cooperation with international agencies, has proposed a plan to improve micronutrient consumption by encouraging increased use of wild edible plants; wild plants have the advantage of being easy to grow, resistant to pests and diseases, locally familiar, and freely available [7]. Research has been undertaken to identify available wild species and current practices involving them, but no efforts to date have been made to determine the amounts and types of wild edible plants that should be eaten to optimize micronutrient intakes. This step is essential in the planning of an effective nutrition intervention program. The objective of this project was to determine the optimal blend of South African wild edible plants needed to fill gaps between typical micronutrient consumption of lactating women in KwaZulu-Natal, South Africa, and their estimated requirements.

METHODOLOGY

Subjects

Dietary and demographic information for this project was taken from the Maternal Nutrition (MN) study, which has been described in detail elsewhere (see [8]). Briefly, the MN study was a prospective longitudinal observational study conducted between May 2002 and August 2004 in rural northern KwaZulu-Natal, South Africa, to investigate the nutritional status of HIV-infected and HIV-uninfected breastfeeding mothers [8]. The population in this area is predominantly of Zulu ethnic origin and is characterized by high rates of HIV infection, unemployment, poor access to clean water, and a high infant mortality rate [9]. All HIV-positive pregnant women attending the 3 antenatal clinics in the region were invited to participate. HIV-negative pregnant women were recruited through a time-related random sample of women attending the same clinics. Women who intended to return to school or work within 2 months following delivery or leave the area within 3 months were excluded. One hundred forty four women were enrolled, 92 HIV-positive and 52 HIV-negative. Enrollment in the MN study began at approximately 6 weeks post partum and follow-up visits took place at 14, 24, 36, and 48 weeks post partum[8].

Diet

Twenty-four-hour recall records were collected at each study visit and were available for 142 women. Records were obtained in participants' homes by trained Zulu speaking staff members so that usual portions and products consumed could be estimated accurately. Data from the 24-hour recalls collected at each study visit were entered into FoodFinder®, a diet analysis program developed for use in South Africa, to determine nutrient intake. Each woman's average intake was determined and used to find the mean intake for the group.

A mandatory food fortification program was initiated in South Africa in October of 2003, requiring that maize meal and wheat flour be fortified with iron, zinc, vitamin A, thiamine, riboflavin, niacin, vitamin B_6, and folic acid [10]. Because fortification began midway through the study, food records were modified to reflect probable post fortification levels. This was done by determining the difference in intake of the fortified nutrients for 34 women with records from both before and after fortification and adding the difference to all pre fortification records. Two-sample t-tests using a significance level of $\alpha=0.05$ were performed to determine if HIV status or season impacted nutrient intake.

Two different sets of values were considered in determining the amount of each nutrient required to optimize the dietary intakes of these women. The first set identified the level of nutrient intake needed to meet the needs of 50% of women, which corresponds to an average intake equal to the U.S. determined Estimated Average Requirements (EAR), while the second amount met the needs of 75% of women. These levels were determined by ranking nutrient intake by quartile and then subtracting the median (50%) and first quartile (75%) values respectively from the EAR. The percentage of women consuming less than the EAR was also identified. Nutrients for which more than half of the women were consuming less than the EAR were targeted for optimization.

Nutrient profiles of wild edible plants

A list of wild edible plants available in KwaZulu-Natal and their nutrient profiles were collected from previously published sources [11-13]. Plants used exclusively for oil, gum, alcoholic beverages, and for medicinal purposes were excluded. Items with improbable energy content for the specified food type were also excluded. The wild edible plants were then organized into food groups: leafy green vegetables (n=32), fruit (n=47), roots and tubers (n=9), and seeds, nuts, and grains (n=9). Nutrient concentrations of boiled leafy greens were used when possible, but these were available for only three of the vegetables (*Amaranthus sp., P. oleracea,* and *U. urens*). All other values were for raw foods. Composite nutrient profiles for the food groups were then created for use in modeling. An attempt was made to weigh nutrient profiles so that commonly consumed items, as determined by food records of the 142 women and published literature, would account for a greater proportion of nutrients as has been done in the formation of nutrient profiles for other food groups (see [14]). Leafy greens were the only type of wild edible plants for which information could be found indicating regular consumption in the region. Amaranth was the only wild leafy green consumed by the MN study participants, and so was arbitrarily assigned 20% weight. Odhav *et al.* [12] identified 8 other leafy vegetables as being regularly consumed in this area (*B. pilosa, C. triloba, C. album, C. monophylla, G. parviflora, M. balsamina, P. oleracea, and S. nigrum*). Each of these eight was assigned 5% weight, for a group total of 40%. An equally distributed average of the remaining 23 locally available leafy greens accounted for the remaining 40%. The equation for determining the weighted leafy green vegetable composite nutrient profile can be summarized as follows:

$$\sum (\text{Amaranth} \times .2) + (\text{Regularly consumed} \times .4) + (\text{Remainder} \times .4)$$

Each item was equally represented in determining the composite nutrient profiles of the other three food groups. No information was available on the vitamin A content of roots and seeds; folate content of fruit, roots, and seeds; vitamin C content of seeds, and the vitamin B_6 content of all groups. Nutrient values from equivalent food groups developed by the United States Department of Agriculture therefore were used as estimates of these values so that these nutrients could be included in the optimization models [14].

Optimizing intake

Linear programming, using Lindo® software, was used to determine the optimal blend of wild edible plants that would need to be eaten to meet the needs of lactating women in KwaZulu-Natal for the targeted micronutrients. Linear programming analysis simultaneously considered the amount of each nutrient provided by each wild food group to determine the smallest total calories of wild edible plants that could be consumed to fill nutrient gaps. Two different optimization models were originally created. The first found the amount of wild edible plants required in addition to the current diet to meet the needs for each nutrient for 50% and 75% of women. The second was an isocaloric model in which all additional calories from wild edible foods would replace the equivalent number of calories from maize meal, which is the food consumed in the greatest amount in this population. It was discovered, however, that no practical solutions were possible for this model. A third, semi-isocaloric model representing the midpoint between these two models, was then developed in which it was assumed that half the additional calories that would be consumed would replace an equivalent amount of calories from maize meal, meaning that for every 100 kcal increase in wild edible plant consumption, maize meal consumption would decrease by 50 kcal.

Limits were set on each food group to ensure portion sizes did not exceed amounts estimated by the author to be reasonable. Limits for leafy greens and fruits were set at 105 kcal (250g) and 300 kcal (375g). Roots and seeds were limited to 110 kcal (150g) and 380 kcal (100g) so that nutrient dense leafy greens and fruits would be emphasized in the mixtures.

RESULTS

Diet

A total of 504 food records were collected from the 142 women, with each woman having an average of 3.5 records. No significant differences were found in nutrient intake by season or HIV status. Average nutrient intakes adjusted to reflect estimated post-fortification levels and comparisons with the EAR are provided in Table 1. More than half the women consumed less than the EAR for calcium, zinc, copper, vitamin A, thiamin, riboflavin, vitamin B_6, vitamin B_{12}, vitamin C, and vitamin D. Consequently, these nutrients, with the exception of vitamin B_{12} and D which are not available from plant sources, were targeted for further analysis. The additional amount of each of these nutrients required to meet the needs of 50% and 75% of women are listed in Table 2.

Optimizing intake

Composite nutrient profiles for a 100g sample of each food group are listed in Table 3. Using these values to calculate the optimal blends of wild edible plant food groups that need to be consumed in addition to the current diet to meet the nutrient needs of 50% of lactating women while minimizing total calories provided resulted in a combination of 250g leafy greens, 176g fruit, and 55g roots and tubers. This blend would increase energy intake by 286 kcal and meet the needs of 75% of women for all nutrients except calcium, thiamin, and riboflavin. To fully meet the needs of 75% of women while minimizing calories, 250g leafy greens, 276g fruit, and 127g of roots and tubers would need to be consumed in addition to the current diet, providing 419 additional calories.

The semi-isocaloric model provides a slightly more simple mixture. The needs of 50% of women can be met through an additional 192 kcal made up of 250g of leafy vegetables (equivalent to 8 cups raw or 1½ cups cooked) and 349g of fruit (equivalent to 2¼ cups or 4 medium peach sized fruits), replacing 54g of maize meal (equivalent to 1/2 cup raw). The total amounts of nutrients provided by this blend are listed in Table 4. How this blend is predicted to impact the overall diet is shown in Figure 1. The same blend will meet the needs of 75% of women for all nutrients except calcium, zinc, thiamin, and riboflavin. To fully meet all requirements of 75% of

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women, 250g of leafy greens, 375g fruit, 22g of roots and tubers, and 97g of seeds, nuts, and grains would be needed, replacing 112g of maize and providing 397 additional calories.

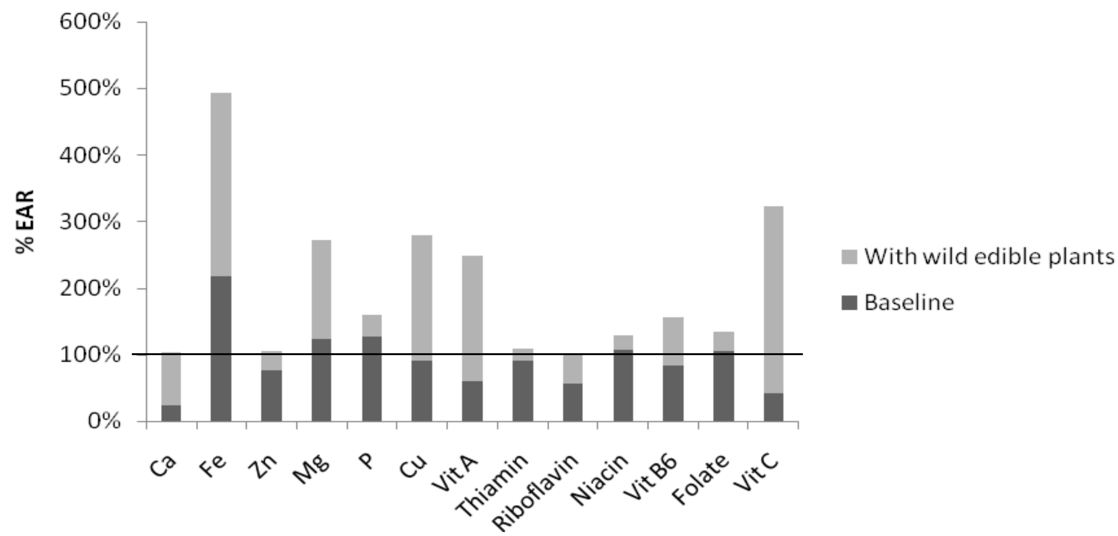

Figure 1: Median percentage of the Estimated Average Requirement for micronutrients currently consumed and predicted improvement if 250g wild leafy vegetable and 349g fruit are eaten, replacing 54g of maize meal

Note 100% EAR meets the nutrient needs of 50% of individuals in a population

DISCUSSION

Following fortification in South Africa, lactating women in the present study consumed adequate amounts of iron, magnesium, phosphorus, niacin, folate, and vitamin E, with low intakes of calcium, zinc, copper, thiamin, riboflavin, and vitamins A, B_6, B_{12}, C, and D. Linear programming models were developed showing how diet quality of this population could be improved by consuming wild edible plants available in the study area either in addition to the current diet or partially replacing maize meal.

While minimizing the total calories of additional food that would need to be eaten, consuming 250g of leafy vegetables, 176g fruit, and 55g of roots and tubers can meet the micronutrient needs of 50% of lactating women without changing any other aspect of the diet. The average energy intake of 1918 kcal in this population is in accordance with recommendations that lactating women who are not physically active consume 1900 kcal per day, making the additional 286 calories provided by this model potentially excessive and an inappropriate recommendation for a population characterized by high rates of obesity [15]. The simpler semi-isocaloric model

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including 250g of leafy green vegetables and 349g of fruit, replacing 54g of maize meal and providing only 192 additional calories, is therefore recommended. The amount of calories this blend would add to the diet is acceptable, particularly if levels of physical activity increased in association with collecting food.

Several nutrients are provided by the recommended blend of wild edible plants in very high amounts. Iron, at 32mg, exceeds the EAR for lactating women by nearly 400%. This level, however, is only slightly above the recommended dietary allowance (RDA) for pregnant women (27mg) and is well below the established tolerable upper intake level (UL) for lactation set at 45mg. Iron from plant sources also tends to have low bioavailability. This amount, therefore, is not likely to have detrimental effects. The amount of magnesium provided (611mg) exceeds the EAR by 170%. There is no UL for dietary magnesium, but excessive intake may be problematic for individuals with impaired renal function. Copper, vitamin A, and vitamin C also exceed the EAR by 178%, 148% and 222% respectively, but all amounts were well below the ULs and not likely to have negative effects [16].

The recommended amount of wild edible plants is higher than the South African national recommendation for fruit and vegetable consumption of 400 total grams per day and much higher than the 141g that are typically consumed in rural areas [17]. Such an extreme change in eating patterns will be difficult to bring about. In addition to the large amount of change, wild plant foods are often looked down upon because of associations with poverty and 'backward knowledge' [18]. An intervention program encouraging the increased consumption of wild edible plants will have the greatest chance of success if nutrition education is incorporated, as has been seen in previous trials [19, 20]. Care must also be taken to not increase negative perceptions of these foods by targeting interventions only towards the poor and individuals with HIV [21]. Presenting the idea in a way that will appeal to both those who would like to return to traditional ways and those who want to be more modern will also be an asset [22]. Maintaining sustainability will be aided by encouraging cultivation of these plants in home and community gardens [23, 24].

One of the limitations of this study is the overall poor quality of data on the nutrient composition of wild edible plants. There is a general lack of information on the chemical composition and nutritional values of wild edible plants in South Africa [25]. Recent interest in the value of wild leafy green vegetables has led to improved knowledge of the nutrient composition of the most common types, but less commonly consumed greens, as well as fruits, roots, tubers, seeds, nuts, and grains, continue to be neglected.

A second limitation, related to the first, was the use of the USDA's composite nutrient profiles for food groups when no other information was available. These values were based on foods typically consumed in the United States and may not reflect accurate values for wild plants in South Africa. Wild plants, however, have often been found to have higher nutrient levels than cultivated varieties [25-27]. It is likely, then, that

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these borrowed values may be under- rather than over-estimates of true wild plant composition.

Micronutrients that were consumed in inadequate amounts in the present study that cannot be obtained through increased consumption of wild plants include vitamins B_{12} and D, which are not typically found in plants. The collection, cultivation, and sale of wild foods can significantly increase income, as has been seen in other populations [28, 29]. It is therefore hoped that increased wild plant consumption will improve economic conditions sufficiently so that more vitamin B_{12} and D rich animal based foods can be consumed to meet these requirements.

CONCLUSION

The results of this project show that it is possible to optimize the micronutrient intakes of lactating women in KwaZulu-Natal through increasing wild leafy green and fruit consumption by approximately 600g per day. This data can provide policy makers with the information necessary to formulate effective nutrition interventions. The high level of recommended change, however, also highlights the need to employ multiple approaches to achieving improved nutrition. Additional information is needed on the availability and nutritional values of wild edible plants in South Africa. Despite these limitations, it is clear that the utilization of wild edible plants can significantly improve the micronutrient status and health of lactating women and their families in South Africa.

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Table 1: Summary of adjusted first quartile, median and third quartile nutrient intakes, Estimated Average Requirements, and the percentage of women consuming less than the EAR. n=142 women

	Q1	Median	Q3	EAR	% below EAR
Energy (kcal)	1564	1918	2285		
Protein (g)	33.5	43.7	53.8		
Fat (g)	44.5	54.2	67.3		
Carbohydrate (g)	237	275	348		
Calcium (mg)	116	239	324	1000†	100
Iron (mg)	12.7	14.1	15.8	6.5	0
Zinc (mg)	6.62	7.99	9.17	10.4	87
Magnesium (mg)	207	276	331	225	35
Phosphorus (mg)	545	737	855	580	30
Copper (mg)	0.76	0.91	1.13	1.0	58
Vitamin A (µg RE)	419	511	583	850	93
Thiamin (mg)	0.90	1.09	1.40	1.2	56
Riboflavin (mg)	0.66	0.74	0.85	1.3	94
Niacin (mg)	11.39	13.96	16.67	13	39
Vitamin B_6 (mg)	1.21	1.41	1.56	1.7	83
Folate (µg)	410	472	540	450	50
Vitamin B_{12} (mg)	0.15	0.70	1.74	2.4	82
Vitamin C (mg)	17.1	29.4	50.8	70	86
Vitamin D (µg)	0.27	0.91	1.96	5.0	96
Vitamin E (mg)	17.7	23.7	27.7	10.0	7

†No EAR is available for calcium, so the Adequate Intake (AI) is used here

Table 2: The amount of nutrients needed to meet the needs of 50% and 75% of lactating women in KwaZulu-Natal

	Nutrient gaps	
	50%	75%
Calcium (mg)	761	884
Zinc (mg)	2.41	3.78
Copper (mg)	0.09	0.24
Vitamin A (µg RE)	339	431
Thiamin (mg)	0.11	0.30
Riboflavin (mg)	0.56	0.64
Folate (µg)	0.0	40.0
Vitamin C (mg)	40.6	52.9
Vitamin B_6 (mg)	0.29	0.49

Table 3: Composite nutrient profiles of South African wild edible plant food groups per 100g

	Leafy vegetables	Fruit	Roots and tubers	Seeds, nuts, grains
Energy (kcal)	41.9	79.6	73.9	377.8
Protein (g)	3.6	1.6	2.4	16.5
Fat (g)	0.6	0.8	0.2	18.6
Carbohydrate (g)	5.8	16.4	15.5	35.9
Calcium (mg)	246	50	102	63
Iron (mg)	5.9	1.5	1.0	4.3
Zinc (mg)	1.2	0.3	0.6	3.1
Magnesium (mg)	101	35	51	206
Phosphorus (mg)	60.8	37.8	44.1	335
Copper (mg)	0.3	0.3	0.2	1.2
Vitamin A (µg RE)	541	99	2.0†	119†
Thiamin (mg)	0.06	0.07	0.05	0.55
Riboflavin (mg)	0.17	0.06	0.03	0.16
Niacin (mg)	0.78	0.72	0.47	1.61
Folate (µg)	57	32†	14.2†	35†
Vitamin C (mg)	36.7	29.8	6.8	0†
Vitamin B_6 (mg)	0.27†	0.12†	0.21†	0.63†

†Nutrient levels from USDA's food group composites [14]

Table 4: Nutrient composition of optimal blend of wild edible plants to meet the needs of 50% of lactating women using a semi-isocaloric model, where half of additional calories are replacing the nutrients in an equivalent amount of maize meal, and the potential impact on total diet

	Leaves (250g)	Fruit (349g)	Maize (54g)†	Net Total (545g)	Diet Total
Energy (kcal)	105	278	192	192	2110
Protein (g)	9.0	5.7	4.6	10.0	53.7
Fat (g)	1.4	2.8	0.7	3.5	57.7
Carbohydrate (g)	14.5	57.3	40.2	31.6	306
Calcium (mg)	616.6	174.9	2.3	789.2	1028
Iron (mg)	14.8	5.2	2.0	18.0	32.0
Zinc (mg)	2.9	1.1	1.0	3.0	11.0
Magnesium (mg)	254	122	41	335	611
Phosphorus (mg)	152	132	94	190	927
Copper (mg)	0.86	1.06	0.05	1.88	2.78
Vitamin A (µg RE)	1356	346	102	1600	2111
Thiamin (mg)	0.14	0.25	0.17	0.22	1.31
Riboflavin (mg)	0.43	0.23	0.10	0.56	1.30
Niacin (mg)	1.97	2.51	1.61	2.87	16.82
Folate (µg)	143	91	102	131	603
Vitamin C (mg)	91.9	104.2	0.0	196.1	225.5
Vitamin B_6 (mg)	0.87	0.60	0.22	1.25	2.66

† Amount eliminated from the diet

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