PN-ACB-788

SEASONALITY IN CAROTENE INTAKE FINAL REPORT

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September 1997

This report was prepared with support from the United States Agency for International Development, Bureau for Global Programs, Field Support and Research, Office of Health and Nutrition under The Food Security and Nutrition Monitoring Project (IMPACT), Contract No. DAN-5110-C-00-0013-00; Task Order 210

ACKNOWLEDGEMENTS

The authors are extremely grateful to Dr G.J.A.Koppert for the re-analysis of his data from Nepal; Dr Howarth Bouis for his patience and co-operation in the re-analysis of his Philippine data set; Mr Akadiri for allowing the re-analysis of his data from North Benin (although this data set was not finally used in this study); Saul Morris who kindly gave essential statistical advice; Mrs Judy Bailey for her patient help and expertise during the difficulties which were encountered in re-analysis of the Philippine data set; Dr R.F. Florentino for current information from the Philippines; and finally to the United States Agency for International Development for providing funding for the project. It must be acknowledged that the project could not have been carried out successfully without the assistance of the above people.

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SUMMARY

Vitamin A deficiency is a major public health problem in many developing countries. In these countries the majority of vitamin A tends to be derived from B-carotene and other provitamin A carotenoids which are relatively cheap sources of vitamin A. Thus the optimum strategy for eliminating vitamin A deficiency in the long term would be to increase the intake of naturally occurring dietary sources of provitamin A. Many factors affect the bioavailability of carotene and retinol and the bioconversion of B-carotene to active vitamin A; these as well as the recommended dietary requirements, efficiency of vitamin A storage, and seasonal differences in intake need to be considered when assessing the sufficiency of vitamin A dietary intake.

This report presents a review of the literature showing the importance of seasonal variation in carotene intake and carotene rich foods. This report also presents the results of the re-analysis of four data sets, using more recent data on carotene content. The re-analysis was undertaken to examine seasonality in carotene intake. The intermediate report for the present project showed the importance of using accurate analysis for the carotenoid content of foods.

The literature review covers factors that affect bioavailability, absorption and bioconversion of carotene. Studies indicate that high intakes of carotene during the season when carotene-rich foods are abundant can provide protection from vitamin A deficiency for up to seven months, if optimal liver stores are achieved during the high season. However, the reduced absorption of carotene by replete individuals needs to be factored into such calculations.

Existing data from the Philippines, Ghana, Malawi, and Nepal were re-analyzed using revised food composition tables for carotene. Where possible, factors which may help to explain any variation in intake were also considered such as sources of vitamin A and their availability and price. Results of the re-analysis showed large statistically significant variations in vitamin A intake over seasons/time which, where possible to evaluate, differed with expenditure quintile and age group. Revision of the food composition tables for carotene resulted in vitamin A intakes being reduced by approximately 50%. The bioavailability, bioconversion and efficiency of vitamin A storage in body tissues were considered when assessing the sufficiency of vitamin A intakes. Re-analysis of the Philippine and Nepal data sets showed group mean intakes for one or more seasons/survey round being below the basal and safe level of requirements. For Ghana and Malawi, only a small proportion of subjects had intakes below the safe level of requirements during all seasons; a relatively high proportion had low intakes for one season only. The Philippine data set showed that the ability of intakes in the high season to cover the deficit in the low season was dependent on the bioconversion factor used. Finally, the Philippine data suggest that agricultural commercialisation has had a negative impact on carotene intake, possibly through reduced local horticulture, lower food availability and higher prices.

The literature review and re-analysis of the four data sets lead to a number of programme recommendations which are summarized as follows:

* improve carotene intake during the season of plenty to increase the protection period;

* identify and promote locally available carotene-rich foods by season and by potential for increased production and consumption;

* improve food composition tables to include local foods analysed for carotene content using modern techniques;

* improve year-round availability of carotene-rich foods by appropriate food processing methods;

* examine the potential of small-scale animal-rearing projects to improve retinol intakes;

* if agricultural commercialization is beginning in an area, monitor the impact on micronutrient intake, and implement a suitable nutrition education programme if necessary.

* target intensive programmes to high risk individuals (or groups), namely those who do not meet their vitamin A requirements even during the season of abundance of carotene-rich foods.

Recommendations for further research are also included in the report. These include the need for further research on the carotene content of foods, and the factors affecting its bioavailabilty, absorption and bioconversion. More work is also needed on good methods of food preservation and methods of assessing vitamin A intake.

The report found very few good studies of seasonal intake of carotene, and none that extended beyond a year. The finding from the Philippine study that commercialization of agriculture may have had a negative impact on carotene intakes needs to be further examined, both in the Philippines and elsewhere. Operational research is needed to see if seasonal abundance can indeed be used to increase protection, taking into account reduced absorption of carotene by retinol-replete individuals. While the report focuses on carotene, it is also recommended that research be undertaken to examine the viability of small-scale livestock projects and to assess their potential for reducing vitamin A deficiency.

INTRODUCTION

The link between vitamin A deficiency and blindness in young children is well established. More recently, evidence has accumulated linking the deficiency with increased morbidity, a greater severity of infections and a higher risk of child mortality. There has been considerable debate about the appropriate strategies for improving vitamin A status in deficient populations. Seasonality in carotene intake may deserve greater consideration in the design of interventions. The present study examined the programmatic implications of seasonality in carotene intake, based on a literature review and a re-analysis of existing data sets.

The report is divided into three sections:

A. A review of the literature on seasonality in carotene intake, and the factors affecting the bioavailability, absorption and conversion of carotene.

B. The re-analysis of four data sets: methods and results.

C. Programmatic implications, conclusions and recommendations.

Figure A gives a representation of the main issues addressed in the report.

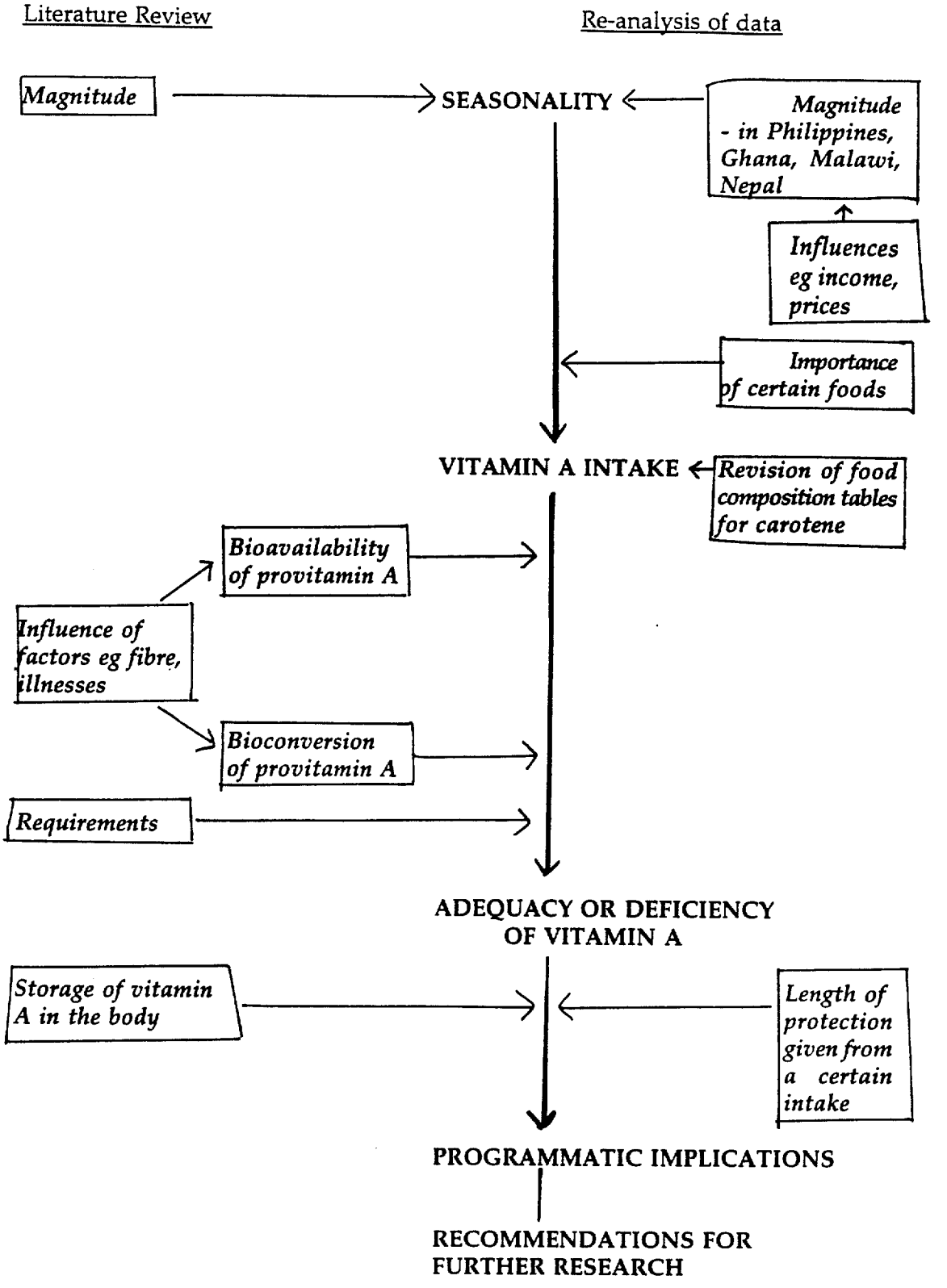
A. LITERATURE REVIEW

Evaluation of vitamin A status and requirements of vitamin A

Vitamin A cannot be synthesized within the body (Bauernfeind, 1980) and is essential for growth, for normal function of the retina, development of epithelial surfaces (Passmore & Eastwood, 1991) and normal development and differentiation of tissues (Department of Health, 1992). The most important manifestation of severe vitamin A deficiency is the irreversible loss of eyesight (Bauernfeind, 1980). Together with greater susceptibility to infections and other accompanying nutritional deficiencies, the condition frequently leads to death (Bauernfeind, 1980; Department of Health, 1992). High dose vitamin A supplementation has been found to significantly reduce mortality (Fawzi et al. 1993) and the severity of complications during measles (Ogaro et al. 1993).

Vitamin A deficiency is a major public health problem in many developing countries (Fawzi, et al. 1993) and clinically evident ocular disease caused by vitamin A deficiency annually affects an estimated 5-10 million children, mostly in the developing world: 5-10 fold more are believed to be subclinically depleted to a level that increases their risk of mortality and perhaps morbidity (cited by Underwood, 1990). Khan et al. (1992) among others suggest that the most appealing long-term solution is to increase the intake of the natural dietary sources of vitamin A or pro-vitamin A carotenoids by young children and women of child bearing age in deficient populations. Most, if not all, vitamin A transferred

Figure A. Issues addressed in the report



to the fetus is derived from hol-retinol binding protein (RBP) in maternal plasma (Olson, 1987) and retinol is transferred primarily to human milk from hol-RBP, which is elaborated in the liver, thus the maternal liver reserves of vitamin A play a crucial role in this transfer process (Olson, 1987). Due to the fact that large supplements of vitamin A or of retinoids may cause birth defects, an excessive intake of vitamin A or of retinoids during pregnancy should be avoided (Olson, 1987).

Vitamin A is usually supplied in the daily diet as preformed vitamin A (retinoids), found in foods such as milk, butter, cheese, egg yolk, liver and some of the fatty fish (Passmore & Eastwood, 1991), as carotenoid vitamin A precursors (provitamin A), found chiefly in red palm oil, green vegetables, yellow and red fruits and vegetables, or as a mixture of the two. Vitamin A is stored mainly in the liver (Bauernfeind, 1980) but also in other body tissues (Blomhoff et al. 1991; Napoli & Race, 1988). Bhaskarachary et al. (1992) cited that currently about 85% of the daily supply of vitamin A in countries such as India where vitamin A deficiency is prevalent, is contributed by B-carotene and other provitamin A carotenoids present mainly in foods of plant origin. They also found evidence to suggest that 95% of the total dietary carotenes are derived from fruits and vegetables (Bhaskarachary et al. 1992).

It is presently widely accepted that over the range of foodstuffs in a normal mixed diet, 6 ug B-carotene or 12 ug of other provitamin A carotenoids are nutritionally equivalent to 1 ug retinol, and the vitamin A activity in the diet, can be summed in retinol equivalents (RE) (Department of Health, 1992). Solomons and Bulux (1993) explain that the assumptions for this expression were that B-carotenes would be absorbed one-half as well as preformed vitamin A and that the average extent of bioconversion is 33%. However, the ICMR Expert Group (1990) in India recommend that the conversion factor for computing the RE of dietary carotenes is 0.25. Rao (1992) states that for all practical purposes 1 ug B-carotene yields 0.5 ug retinol and it is suspected that the conversion efficiency may be higher than one. Rao (1992) also states that the retinol equivalent of other carotenes is almost one half of B-carotene.

Napoli and Race (1988) state that mobilization of retinol from liver stores and transport to target tissues by the serum RBP may not be the sole mechanism for the support of retinoic acid-dependent processes in animals that are 'carotenoid accumulators' such as humans. They state that the ability of B-carotene to generate retinoids in tissues, independently of the well-controlled release of retinol from liver, implies that carotenoids with provitamin A activity may have more extensive roles in retinoid homeostasis than has been realized. Blomhoff et al. (1991) stated that in response to a small dietary intake of the vitamin, normal plasma retinol concentrations may appear to be maintained within a certain range of the normal set point by numerous homeostatic mechanisms. In contrast, in the face of large fluctuations in dietary vitamin A intake, controlled secretion of retinol by the liver may be a key regulatory element for maintaining plasma retinol concentrations ie. the liver may act like a balloon in that it is able to absorb a large input during positive vitamin A balance by storing the excess retinol and in that it can then release its stores during negative balance (Blomhoff et al. 1991).

Adequate vitamin A status can be defined in terms of an adequate body pool, based on the amount of vitamin A in the liver (Department of Health, 1992). A liver concentration of 20 ug retinol (or the equivalent in esterified form) per gram wet weight (0.07 umol/g) was used

by the Department of Health (1992) and FAO/WHO (1988) to establish requirements of vitamin A in normal healthy persons. This concentration meets the following criteria (Dept. of Health, 1992; Olson, 1987): no clinical or biochemical signs of deficiency have been noted in subjects with this liver concentration; it maintains adequate plasma retinol concentrations; and it should maintain an adult on a diet containing no vitamin A free from deficiency signs for a period of several months (approximately 4 months (Olson, 1987)). This liver concentration is used increasingly in the international scientific literature as a reference point of vitamin A adequacy (Olson, 1987). Using a mean fractional catabolic rate the mean daily dietary intake needed to maintain this liver retinol concentration can be calculated using several assumptions: the liver weight to body weight ratio is 0.03 (mean value in adults is 0.024; for children 0.042); the liver reserves represent 90% of the total body vitamin A; the efficiency of storage in the liver of an ingested dose of vitamin A is 50% (Department of Health, 1992; Olson, 1987).

Using the following assumptions hypothetical liver storage and protection periods for a healthy 15 kg child were calculated (cited by WHO (1976): the body wt/liver wt ratio = 0.03, 20% of an oral dose of vitamin A is stored in the liver, the half-life for liver depletion is 50 days, the daily vitamin A requirement of a 15 kg child is 400 ug retinol, and final depletion rate is linear at 80 ug vitamin A /d. For a liver vitamin A (ug/g) of 100, 40, 20, and 10 the corresponding protection periods were calculated to be 220, 156, 106 and 56 days respectively. The occurrence of fatty liver, should be taken into account in making the calculation of total body stores by suitably increasing the liver wt to body wt. ratio. The protection period will be affected by the child's rate of growth, stress of various kinds, the integrity of the plasma transport system, and liver disease (WHO, 1976). Olson (1978) also calculated protection periods using the same assumptions stating that the liver depletion rate is first-order (also cited by Blomhoff et al. 1991) down to a vitamin A level equivalent to the utilization rate and then is linear thereafter. Blomhoff et al. 1991 also cited that if dietary vitamin A intake is zero, the liver vitamin A depletion rate is equivalent to the vitamin A utilization rate. Olson (1978) notes that at very low liver concentrations ie. 5 ug/g, the value of the calculated protection period, 28 days, is problematic as other factors come into play.

Olson (1978) states that the selection of a suitable protection period is a social and not a scientific one, 100 days being chosen as suitable because this is long enough to provide children with a reserve which might sustain them over a seasonal change of diet or a span of health, but not so long that a significant proportion of otherwise healthy children would be considered as marginally nourished in vitamin A. Olson (1978) states that as a liver store of 20 ug/g vitamin A should provide protection for a little more than 100 days any value above 20 ug/g can be considered to be acceptable: values between 10-20 ug/g can be considered as marginal, 5-10 ug/g as poor and values less than 5 ug/g as very poor.

In countries where the availability of carotene-rich fruits and vegetables is seasonal (mango season, vegetables in winter) there are periods of plenty (and even glut) and periods of scarcity (Rao, 1992). Rao (1992) suggests that it may be practical nutrition policy to recommend a higher intake of carotene-rich foods during the season of plenty, to compensate for the low intake during periods of scarcity: the daily average intake of carotene through these foods during the surplus period may be two to three times the RDA, while during the period of scarcity the intake may be almost nil or at least less than the RDA. Rao (1992) cautions that when drawing up dietary guidelines for carotene intake, the

possible effects of high dietary intakes of carotene on the reduced efficiency of their absorption and conversion to retinol should also be considered (Rao, 1992). Rao (1992) demonstrated that the daily per capita availability in India of carotene from all the carotene-rich fruits and vegetables is only 1,165 ug as against the per capita requirement of 2,291 ug. Thus as the current production of fruits and vegetables in India can meet only 50% of the vitamin A requirement of its population there is need for horticultural research and development to boost the production of carotene-rich food and particularly green leafy vegetables (GLV) to meet the shortage. Rao (1992) also states that in India there is a need to exploit a number of unconventional sources rich in carotene eg. dehydrated GLVs, spirulina and red palm oil.

Bioavailability, absorption and bioconversion of vitamin A

1. ***Bioavailability and absorption***

Willett et al. (1983) state that subgroups of the overall population with low vitamin A intake or low marginal serum retinol would probably be responsive to vitamin A supplementation. They found no statistically significant effect of vitamin A supplementation (as retinyl palmitate) on plasma retinol levels of healthy males and females. Similarly, Jacques et al. (1993) found no correlation between plasma retinol and vitamin A intake (assessed by food frequency questionnaire) in their reasonably well-nourished subjects.

Willett et al. (1983) showed that pure B-carotene supplementation increased B-carotene plasma levels. Similarly, Jacques et al. (1993) observed a 36% increase in mean total plasma carotenoid concentrations across the quintiles of provitamin A intake. Brown et al. (1989) found a large variation in the plasma response to B-carotene dosing in healthy men both from pure B-carotene and from dietary sources: the rate of appearance of B-carotene in the blood was relatively slow. Brown et al. (1989) cited that the rate of appearance was supported by some previous research but not by others. The bioavailability of carotenoids in many foods is not as great as that from purified B-carotene (Brown et al. 1989; Olsen, 1987; Rao & Rao, 1970) or that from preformed vitamin A (Olsen, 1987). Solomons and Bulux (1993) reviewed studies in Guatemala which tried to quantify intact B-carotene bioavailability: in one study, either 15 or 30 mg of isolated B-carotene provided to schoolchildren resulted in a maximal mean postdose increase in plasma B-carotene of 8 +/- 9 and 14+/-13 ug/dL, respectively; another study showed on a mg-for-mg basis, increments of B-carotene at the 8 hr interval from carrots (median 27 mg) were one-third those seen with the isolated chemical; a third study showed that in schoolchildren given 20 daily 6 mg doses of B-carotene in capsule form, a 3 fold increase over initial levels of plasma B-carotene at day 10 and 20 was seen, whereas no increase was seen in subjects given the same amount as 50g of cooked carrots. Brown et al. (1989) showed that the steady state plasma concentration in healthy men of individual carotenoids is changed only slightly by a single, large intake of a green leafy or yellow vegetable, and that each individual had a relatively stable, characteristic plasma profile. They suggest that because several apparently healthy men were consistently poor absorbers plasma carotenoid levels may not accurately indicate dietary intake.

Olsen (1987) stated that in physiological amounts carotenoids are not absorbed as efficiently as retinol ie. 20-50% and 70-90% respectively; and as the amount increases the efficiency of carotenoid absorption falls markedly (< 10%)whereas that of retinol remains high (60-80%). Lala & Reddy (1970) found that the absorption of B-carotene in children with a mild degree of protein-energy malnutrition ranged from 57-93% with a mean of 70%; absorption of total carotene ranged from 54-90% with a mean of 75%. However, assessment was made by the balance study and Rao (1992) states that it is possible that carotene is destroyed by the gut bacteria, resulting in an underestimation of excretion and an overestimation of absorption. In healthy young male subjects Rao & Rao (1970) found that the absorption of B-carotene was much higher than that for total carotene. They showed that the absorption of carotene including B-carotene from various dietary sources varies considerably eg. B-carotene from amaranth ranged from 52.4-99.8% with a mean of 75.7% and that from papaya ranged from 73.3-99.4% with a mean of 90.3%. The authors suggest this difference may be due to the fibre content of the foods, the latter containing much less than the former. Both Lala & Reddy (1970) and Rao & Rao (1970) suggested that as a 50% absorption of dietary carotene appears realistic and if efficiency of conversion of B-carotene to retinol is assumed to be around 50%, 4 ug of B-carotene would be equivalent to 1 ug of vitamin A. However, they assessed absorption by the balance method which has been criticized by Rao (1992) who states that in all human studies, carotene absorption has been determined by the balance procedure and there is therefore a need to examine carefully this aspect of methodology of carotene absorption and devise alternative, more reliable, procedures.

2. ***Bioconversion***

The absorbed carotenes are converted into retinol in the mucosal cell of the small intestine by the action of the enzyme carotene dioxygenase (Rao, 1992). In contrast to Lala and Reddy (1970) and Rao and Rao (1970), who suggest the ratio of B-carotene to retinol should be 1:4, Solomons and Bulux (1993) question whether the efficiency of bioconversion of provitamin A compounds into the active vitamin is as good as is currently accepted, and Blomhoff et al. (1991) conclude that in view of the work they reviewed, the mechanism of conversion of carotenoids to retinol in vivo merits further research. Rao (1992) suggests that since the retinol equivalent of carotene can vary from one food to another, it is preferable to have RE values for each of the carotene-rich foods. The RE of carotenes in foods can be computed as follows: RE (ug/100gm) = B-carotene content (ug/100gm) x 0.5 x % absorption/100 + content of other carotenes (ug/100gm) x 0.25 x % absorption/100 (Rao, 1992). Bioconversion of carotenes involves their hydrolysis in the gut to yield the active vitamin in the form of retinal (Solomons & Bulux, 1993). Solomons and Bulux (1993) cite a study which found detectable increments in retinyl esters in 16 of 20 poor rural schoolchildren, following 30 mg of an oral dose of B-carotene in capsules. On the other hand, there was no detectable ester response after meals of carrots containing 12-950 mg of B-carotene in well-nourished urban schoolchildren. However, vitamin A status affects the rate of secretion of retinol-RBP (cited by Blomhoff et al. 1991) and as these children were well-nourished, the hepatocyte retinol-RBP secretion may have reached a saturation point where RBP becomes rate limiting, as described by Blomhoff et al. (1991). Although Solomons and Bulux (1993) cite some studies that have reported a dramatic circulating retinol response to the chronic administration of plant sources of provitamin A they criticize these because of their small sample sizes, lack of randomisation and the fact that there was

no placebo group. Willett et al. (1983) found that pure B-carotene did not materially increase plasma retinol levels in their healthy adults.

Solomons and Bulux (1993) review a study of French vegetarian and non-vegetarian adults: vegetarians of both genders had the higher plasma levels of alpha and B-carotene. However, 3% and 6% of vegetarian men and women respectively compared to none of the non-vegetarians had a circulating blood retinol level of <30ug/dl. The intakes of these subjects were 1900 RE (with 0.5 mg preformed vitamin A and 8 mg from carotenoids) and 1500 RE for men and women vegetarians respectively and 1400 RE daily (0.8 mg from animal sources and 3.6 mg from plant carotenoids) for both men and women non-vegetarian. Although Solomons and Bulux (1993) suggest that the conversion factors of 1:6 for B-carotene may be too high, the use of the vegetarian study in their argument may not be valid if the food composition table analysis used in the study (not stated in the study by Millet et al. 1989) did not use a method such as HPLC which separates the carotene fractions: recent analysis shows carotene contents are overestimated in many foods if older methods of analysis have been used.

Factors affecting the bioavailability, bioconversion and utilization of vitamin A

Dietary fat, protein, vitamin E, antioxidants, and zinc all enhance the absorption and utilization of carotenoids and retinol. On the other hand, peroxidized fat, other oxidizing agents, such as inorganic and poorly absorbable iron, dietary fibre, large doses and deficiencies of alpha-tocopherol depress absorption (Olsen, 1987; Hathcock et al. 1990; Solomons & Bulux, 1993; cited by Olsen, 1987). Solomons and Bulux (1993) cite that the role of fat in the absorption of carotene is due to the exocrine secretory mechanisms (bile salts, pancreatic lipase) and the mucosal responses (packaging of fats into lipoproteins) being stimulated and regulated by the magnitude of fat in the diet. Solomons and Bulux (1993) state that dietary fibre could act by microencapsulating carotene within an indigestible matrix or binding the compound in a hydrophilic milieu that would exclude it from the mechanisms of lipid absorption. In addition, Solomons and Bulux (1993) state that the potential influence of iron would be to act as an oxidant, destroying or isomerizing the carotenoids prior to their absorption. Protein deficiency impairs the transport of retinol (even when hepatic reserves may be sufficient) by decreasing the hepatic biosynthesis of retinol binding protein and transthyretin, both of which are required for retinol transport and release from the liver (cited by Carlier et al. 1992).

Infective agents may result in the reduced absorption of vitamin A found in children with bronchopneumonia, acute gastroenteritis, diarrhoea, tropical enteropathy, and chronic protozoal and helminthic infections, sprue (Sivakumar & Reddy, 1978; cited by Solomons & Bulux, 1993; cited by Olson, 1987). Children with ascariasis were found to have a lower absorption of vitamin A than normal children (Sivakumar & Reddy, 1978). Olson (1987) stated that chronic liver disease and the chronic ingestion of alcohol impair the liver storage of vitamin A; and that some drugs and toxic substances also lower liver reserves, probably by enhancing its catabolism (Olson, 1987).

Solomons and Bulux (1993) give two other reasons that could possibly explain why provitamin A sources may not optimize human vitamin A reserves. First, bioconversion may not be regulated to maintain ideal hepatic reserves and thus may only be activated in severe deficiency and the up-regulation may be turned off before adequate reserves have been attained; and second, nature may be cautious of vitamin A toxicity so that down-regulation of bioconversion of carotenoid to vitamin A may be initiated long before the liver can accumulate an abundant reserve of the vitamin.

Although knowledge on some aspects of vitamin A metabolism have advanced recently, such as the extensive recycling of retinol among plasma, liver, and extrahepatic tissues (Blomhoff et al. 1991) and the irreversible disposal rate of retinol decreasing as the (liver) reserves of retinol approach depletion (cited by Chytil, 1992), some topics are still controversial (Blomhoff et al. 1991). Factors that regulate plasma retinol concentration and the mechanisms responsible for cellular uptake and intercellular transport of retinol have not yet been determined. Also, questions such as the nature of the interactions between vitamin A and thyroid hormone, growth hormone, iron status and zinc metabolism, and how retinoic acid production is regulated in target cells, have not been answered.

The efficacy of pharmacological doses of vitamin A to maintain serum retinol levels is controversial (Carlier et al. 1992). Exposure to undernutrition or infection can cause the failure of a single oral dose of vitamin A otherwise sufficient for 8-12 weeks (Carlier et al. 1992). Carlier et al. (1992) found that children with abnormal cytology had significantly lower serum retinol values than those with normal cytology. However, no relationship between cytological abnormalities and B-carotene levels was found. No clinical signs of vitamin deficiency were observed during their investigation in spite of a high percentage of children having serum retinol values lower than 0.35 umol/l (40) and abnormal ICT results (64.9). Carlier et al. (1992) previously observed that in Senegal, very low retinol levels were not correlated with clinical zeropthalmia which they state differs from data obtained in Indonesia. Mariath et al. (1989) noted that the appropriate cut-off values for the blood level of vitamin A are under discussion: although serum values of retinol can be lowered by factors such as infections and protein-energy malnutrition the lower circulating values of retinol do not necessarily indicate tissue depletion. Mariath et al. (1989) also state that conversely severe corneal xerophthalmia can occur in children with serum retinol levels above the traditionally accepted critical cutoff value of 100 ug/L.

Impact of provitamin A in the diet on alleviating vitamin A deficiency

Lala and Reddy (1970) state that the incidence of vitamin A deficiency is particularly high among preschool children belonging to poor income groups. Vitamin A requirements of depressed communities are generally met through consumption of provitamin A carotenoids (Lala and Reddy, 1970; cited by Tarwotjo et al. 1982). Bhaskarachary et al. (1992) calculated that to meet the daily vitamin A requirement, just 20 g of agathi or drumstick would be enough, provided there were no cooking losses; Chaddha (1992) suggested 50 gm of common leafy vegetables like amaranth would provide adequate B-carotene to meet the vitamin A requirements of adults. Carlier et al. (1992) state that the large consumption of mangoes by children may explain the absence of clinical signs of xerophthalmia during the

dry season due to the generation of vitamin A stores as mangoes are carotenoid-rich. Although Tarwotjo et al. (1982) state that few studies have demonstrated consistent differences in dietary patterns between xerophthalmic and normal preschool age children residing in the same milieu and that several studies have failed to find any dietary differences at all, they found in their study that children with xerophthalmia were less frequent consumers of vitamin-A and provitamin A-rich foods than were normal children; and that sources of provitamin A carotenoids played a major role, differences in stated consumption being confirmed by serum carotene levels. They found that the relative risk of corneal disease was inversely related to the frequency of consumption of dark green leafy vegetables and carrots in their hospital study: The risk of corneal disease was 3.7 and 7.3 times higher among those never consuming DGLVs than among those consuming DGLVs less than once a week and at least once a week respectively. They also found that in their countrywide study oil was consumed more frequently by normal children than by those with Bitot's spots. The differences in DGLV consumption by study children were not due to differences in availability or use by their families. The results by Mariath et al. (1989) suggested that buriti sweet (whose oil is 10 times richer in B-carotene than the oil from the red-palm fruit) was effective in improving vitamin A status as indicated either by repletion of hepatic reserves (negative RDR) or by partial or complete regression of clinical signs and symptoms.

Napoli and Race (1988) suggest that the ability of B-carotene to generate retinoids in tissues, independently of the well-controlled release of retinol from liver, implies that carotenoids with provitamin A activity may have more extensive roles in retinoid homeostasis than has been realized. In addition Hathcock (1990) cited that overall B-carotene is not carcinogenic, mutagenic, embryotoxic, or teratogenic and does not cause hypervitaminosis A. It is due to the above findings and the fact that in undernutrition retinol delivery to peripheral tissues from liver is homeostatically regulated by RBP, whereas carotenoid accumulation in tissues does not seem to be controlled but is directly dependent on serum levels that Carlier et al. (1992) suggest that future approaches to alleviate the problem of vitamin A deficiency through public health considerations should, therefore, include B-carotene supplementation.

Tarwotjo et al. (1982) found in their study in Indonesia, that although mango and papaya are cash crops, they were consumed by large numbers of children and these foods are introduced early in the weaning period: during the 2nd and 3rd year of life their consumption was strongly associated with the absence of xerophthalmia. Their age-specific comparisons, possible with the large number of children in the countrywide survey, indicate a dominant role for breast-feeding early in life, for consumption of carotene-rich fruits during the weaning period, and for DGLV consumption thereafter. Mele et al. (1991) found that routine inclusion of foods high in vitamin A (DGLV, yellow fruits and vegetables, and egg) during weaning in Indonesia were associated with a protective effect against xerophthalmia throughout the preschool period. Acceptability must be a major concern in any programme attempting to introduce provitamin A rich foods into the diet: Mariath et al. (1989) state that attempts to introduce DGLV into the diet in northeast Brazil would face serious difficulty because, especially in the semiarid regions, DGLV are considered suitable only for animal feed.

Implications of bioavailability and conversion factors in estimating the sufficiency of vitamin A activity in diets

It appears that the conversion factor for B-carotene equivalents into RE for subjects with a satisfactory vitamin A status is likely to be higher for those depleted of vitamin A stores (Blomhoff et al. 1991). Hence the ICMR Expert Group in India recommends a higher factor (0.25)than the UN agencies (0.167). However, in addition to vitamin A status, other factors affect the availability, absorption and bioconversion of carotenes and retinol such as the fibre, fat and protein content of foods, and illnesses. It would certainly be more accurate not to have a single conversion factor such as at present but rather to estimate a conversion factor and absorption efficiency after assessing the vitamin A status of the study population, its dietary pattern and the prevalence of gastrointestinal and other illnesses. Furthermore, Rao (1992) recommends that each food should be assigned an RE value reflecting its own rate of absorption.

Requirements for vitamin A in RE are based on a catabolic rate, the fact that the efficiency of storage in the liver of retinol equivalents is estimated to be about 20-50% (cited by Olson, 1978; UK Dept. of Health, 1992) and the fact that the liver reserves represent 90% of the total body vitamin A (UK Dept. of Health, 1992).

Olson (1978) evaluated vitamin A status by estimating protection periods. He used the following considerations: the recommended daily allowance; a storage efficiency of dietary vitamin A; the liver depletion rate (first order down to a vitamin A level equivalent to the utilization rate and then linear thereafter; half-time depletion is 50 days in preschool children); and the ratio of liver mass to body weight.

If appropriate estimations for the following are made: the absorption and bioavailability of retinol and carotene; the bioconversion of carotenes to retinol; the daily dietary requirement; the present liver concentration; the liver depletion rate; the half time of depletion; and the magnitude of seasonal differences in vitamin A intake, it may be possible, albeit with crude assumptions, to assess whether an excess of vitamin A or carotene intake in one season is sufficient to build stores to last throughout a season where intakes are poor.

Effect of seasonality on the consumption of vitamin A rich foods and vitamin A deficiency

Xerophthalmia is associated with, among other things, particular seasons in which precipitating events occur (WHO, 1976). Cohen et al. (1983) found a marked seasonal variation in both xerophthalmia and severe PEM in Bangladesh which they state is often observed in marginal subsistence societies: the most influential precipitating events for these nutritional states in Bangladesh were gastro-enteritis and measles (Cohen et al. 1983). Hennig et al. (1983) found a seasonal variation among cases in south-east Nepal, with 43% of noncorneal xerophthalmias and 49% of corneal xerophthalmias being seen between May

and August. They found that most of these children were malnourished and had recently suffered a diarrhoeal illness.

In parts of Indonesia where xerophthalmia endemicity is high, the disease tends to occur all the year round but more frequently in some seasons than in others (WHO, 1976). In addition, the vitamin deficiency only becomes overt when most of the risk factors operate simultaneously, as in Jordan (WHO, 1976). Tarwotjo et al. (1983) cited a study in East Java where there was a peak season for Bitot's spots while the prevalence of corneal xerophthalmia stayed the same. In this same study there was a strong relationship between Bitot's spots and corneal xerophthalmia and a lack of association between malnutrition and either Bitot's spots or corneal xerophthalmia (Tarwotjo et al. 1983). Tarwotjo et al. (1983) found that in Indonesia, while children with xerophthalmia tend to be malnourished more often than their peers, community levels of malnutrition do not appear to be good predictors of the prevalence of xerophthalmia. Sturchler et al. (1987) in Tanzania found that after adjusting for age the association of serum retinol with mid upper arm circumference was maintained in age groups 6-10 and 11-15 years, but not in age group 0-5 years. Cohen (1985) found that the monsoon months in Bangladesh, coinciding with diarrhoeal disease, measles epidemics and a shortage of dark green leafy vegetables were the periods of greatest risk of xerophthalmia; they found seasonal variation to be an important independent risk factor.

Sinha and Bang (1973) found that the two definite peaks of vitamin A deficiency in Bengali children does not seem to be fully explained by variation in intake of vitamin A and they suggested also an association with seasonal variation in growth, related to total food intake ie. during the seasonal growth spurt in the winter months the vitamin A intake is poor leading to signs of deficiency a few months later. Alternatively, the shortage of food during July to September leads to a relative increase in the consumption of locally freely available edible leaves rich in vitamin A; although this was not found to be sufficient to relieve the deficiency, if it is associated with a decrease in growth due to food shortage, the authors felt this may explain the reduction in deficiency signs (Sinha & Bang, 1973).

Of the food consumption studies reviewed in this project, most show an inverse relationship between seasonal intakes of energy and of vitamin A (Adams, 1992 in Bamana, Mali; Lukmanji, 1987 in Tanzania; Kusin et al. 1984 in Machakos, Kenya). In some cases the variation in vitamin A intakes over the seasons has paralleled the variation in retinol levels (Tanner & Lukmanji, 1987). Two studies were reviewed which carried out food consumption studies with the main objective being to assess the seasonal intakes of vitamin A (Abdullah & Ahmed, 1993; Villard & Bates, 1987). It should be noted however that of all the large food consumption studies reviewed which reported vitamin A intakes, it appears that only the study by Villard and Bates (1987) used accurate food composition data for carotene-containing foods: food samples in that study were collected and analyzed in a laboratory using the HPLC method.

WHO (1976) suggested that seasonal variations of xerophthalmia should be investigated to determine whether they are associated with food availability, seasonal diarrhoea, exposure to sunlight etc. In addition Flores & Flores (1984) concluded that it is important to elucidate the main natural and nonnatural factors that affect the nutritional status of the people, especially young children, in each month of the year: in each country, knowledge of the most critical period and the most affected area will help to orient policy makers to plan and

select effective measures for preventing detrimental effects on the health and nutrition of the population. Various food consumption studies over seasons have been carried out in areas where vitamin A deficiency is likely to be a public health problem. The following is a brief review of these studies.

Villard and Bates (1987) showed large seasonal variations in the vitamin A intake of 98 pregnant women and 138 lactating women in the Gambia using direct weighed food intakes and HPLC analysis of the carotene content of foods. They explained that the major peak in intake during April-June was derived from both mangos and palm oil.

Raghuvanshi and others (pers. comm.) report an exploratory study of B-carotene intakes of 225 farm families from two regions of Uttar Pradesh, India, over two seasons from 1992-93 using the 24 hr recall method. They report that B-carotene intakes were greater in the winter season and differences in intakes were due to the availability of carotene sources in the particular season and to the types of crops and vegetables grown on the farm. Consumption of grain leaves, mustard leaves, radish leaves, pumpkin leaves and cabbage was frequent due to their low cost and abundant availability during November to February (winter) whereas in the summer months (May to August) bitter gourd, bottle gourd, pumpkin, ridge gourd, bringal, cucumber and okra were used more frequently. Average intakes of B-carotene in both seasons was less than the RDA for total vitamin A for Indians (these were one fifth for marginal and small farm families of one region). They report that intakes in general were higher in medium and large farm families. They explain that families with small land holdings tend to grow mainly cereals and as the land holding increased diversification of crops including vegetables increased. Although all the families tried to provide some amount of milk to their children the medium and large farmers tended to own milk cattle and thus vitamin A intake in these groups was higher.

Zeitlin et al. (1992) studied the vitamin A intakes of 370 mothers and 183 children in rural Bangladesh from January to July 1986 using one 24 hr recall/month and showed that seasonal low prices and home availability appeared to increase consumption of vegetables, in lower and middle status groups whereas the highest ranking groups did not consume the larger amounts that would have been affordable to them. Cheap greens abundant in January were apparently not fed to infants.

Abdullah and Ahmed (1993) used the IVACG method (a simplified dietary questionnaire and 24 hr recall) to examine the 24 hr and habitual intake of sources of vitamin A of 121 young children in Bangladesh. They discuss the large seasonal variations in the habitual intake pattern of vitamin A and confirm the necessity of obtaining information on the usual consumption patterns of seasonally available food sources of vitamin A, in addition to 24 hr intake estimates to assess intakes.

Kusin et al. (1984) in Machakos, Kenya studied seasonal variation in dietary intakes in 366 pregnant and 244 lactating women using a validated semi-quantitative 24 hr recall. They state that seasonality was most pronounced for vitamin A and ascorbic acid intakes and that the peaks coincided with the availability of leafy vegetables and yellow pumpkin.

Benefice et al. (1984) in Senegal studied food intakes of approximately 500 nomads at 5 different times during the year (March '80-June '81) by the 5 day weighed intake method. Vitamin A intake was highest in the wet season (818 ug RE) and lowest at the end of the

dry season (199ug). They explain that the poor milk production at the end of the dry season explains why vitamin A requirements are not met. The increased intake of vegetables from 6.6g to 43g per head and the increase in fruit from 0g to 3g and fish from 3g to 10.3g could also explain the increase in vitamin A intake.

Flores and Flores (1984) describe the findings of various studies on seasonal intakes of nutrients in Central America. In El Salvador in 1954, intakes of vitamin A of 600 families tended to be highest in the dry season (638ug compared to 438ug per person) whereas other nutrients including energy tended to be higher during the rainy or postharvest season. In contrast, seasonal food consumption of 38 families in Panama in 1952-53 showed green vegetables, fruits and dairy products to be highest in the rainy season when consumption of the staple foods (rice and bananas) was highest. The authors reported that in three rural areas of Honduras there was an increase in the staple food (corn) consumption in the rainy (or postharvest) period. Consumption of dairy products and green vegetables also increased in this season but consumption of fruits decreased. In Guatemala in 1977, 30 families with children were randomly selected in 12 communities for each period. One 24 hr recall was used to estimate intakes. Consumption of green vegetables and the staple, corn, increased in the postharvest period whereas the intake of fruits was highest at the preharvest season. Flores and Flores (1984) observed that the data on children did not show the same seasonal trends as that observed in families. Nutrient analysis showed that for both families and children that vitamin A and vitamin C are highest in the preharvest season whereas all other energy and nutrients examined are highest in the post harvest season. It was observed that the changes in retinol equivalent intake over seasons varied between communities. Where there was a significant difference in intake over periods the retinol equivalent intake decreased in the post harvest season. However, some communities showed no statistically significant change. As in each of the 12 communities only 30 families with children were observed by one 24 hr recall the numbers may be too small to measure the intake of one community accurately.

Adams (1992) reported marked seasonal differences in vitamin A intakes of 33 households in Sebekoro, Mali. The increased intake in vitamin A intake in the dry season coincided with a decreased energy intake. Rosetta (1988) showed seasonal vitamin A intakes in Senegal of 40 households obtained by the 5 day weighed intake. Although vitamin A intakes increased in the rainy season (from 404ug to 555ug per head) this increase was not statistically significant.

Tanner and Lukmanji (1987) in Tanzania showed that seasonal pattern of diet did significantly influence vitamin A intake. They reported that the requirements were fully met in February but a deficiency of vitamin A intake was noted in August, and this could be related to a scarcity of leafy vegetables in the diets during the post harvest season.

The review of studies generally shows seasonal variations of vitamin A intake which is often dependent on the consumption of specific, rich sources of the vitamin. Flores and Flores (1984) however found that although there was a seasonal variation in food availability the effects on food consumption were not clear. They concluded from their mesoamerican studies that dramatic seasonal effects are not observed due to the ability of families to generate some income. In some of the studies the seasonal effect on food consumption and vitamin A intake was not found to be the same for different age groups and income groups.

The prevalence of seasonal variation in clinical signs of vitamin A deficiency has been found to be related to factors such as diarrhoeal disease, measles epidemics, as well as shortage of vitamin A rich foods. Tarwotjo et al. (1982) cited that of these numerous factors which contribute to vitamin A deficiency, inadequate dietary intake is generally considered to be the most important. IVACG (1993) however report that the relationship between vitamin A intake and vitamin A status is highly variable.

Programmes to alleviate vitamin A deficiency rely on long term and short term methods and often a combination of both. Vitamin A deficiency disease control strategies usually fall into one of the following categories: vitamin A supplementation, dietary modification, food fortification, prevention and management of disease and breastfeeding promotion (UN ACC/SCN, 1994). The UN ACC/SCN (1994) have recently reported evaluations of these different interventions.

Seasonality is one of the basic causes of vitamin A deficiency (UN ACC/SCN, 1994) and should be an important consideration in the design of interventions to alleviate the deficiency. Due to the importance of seasonality and due also to the recent findings of the importance of using revised food composition analysis for carotene (using the HPLC method) the present study was designed to look in greater detail at the issue of seasonality in the design of program interventions.

B. THE RE-ANALYSIS OF THE DATA SETS

Existing data sets potentially suitable for re-analysis to examine seasonal variations in carotene intake were identified. Four data sets were found to be suitable for re-analysis after full consideration was given to sample size, methodology and other important characteristics. Detailed documentation of the data assessment procedures and a literature review of dietary survey methodology can be found in the Intermediate Report (Rushton et al, 1994)

The following questions were addressed by the re-analysis:

1. What is the magnitude of seasonal differences in carotene intake?

2. How do economic factors (food prices and income) influence the vitamin A intake of the study population?

3. If large seasonal differences in carotene intake do occur, is the vitamin A intake in the high season sufficient to cover the season of deficit?

4. In light of the analysis (and the literature review), what are:
   a) the implications for programmes to reduce vitamin A deficiency, and
   b) the recommendations for further research?

DESCRIPTION OF EXISTING DATA SETS

Table A gives a brief summary of the four data sets which were used for re-analysis. They are also fully described below.

1. Philippines

Source. Dr Howarth Bouis, International Food Policy Research Institute, 1200 17th Street, N.W., Washington, D.C. 20036-3006.
For full details see Bouis and Haddad (1990) and Bouis (1991).

Study area. The existing data was collected in the southern part of Bukidnon Province, midway between the two principal cities of Mindanao Island, South Philippines (Bouis & Haddad, 1990). Data were collected in connection with a study of the effects of agricultural commercialization in Bukidnon. The food consumption data were collected in order to investigate micronutrient intakes (Bouis & Haddad, 1990). Some areas are flat and suitable for irrigation and other areas are gently sloping or hilly. Most farms have relatively easy access to markets for their output (Bouis & Haddad, 1990). The area was primarily devoted to semi-subsistence corn production (there were small areas of irrigated rice production (Bouis & Haddad, 1990) until the establishment of a sugar mill in 1977 (Bouis, 1991).

Study population. Stratified random sampling was used to obtain 510 households primarily engaged in corn and sugar production who were interviewed during the first round. Due mainly to outmigration only 448 households were present for all four rounds. Data from these 448 households were used in the existing analysis. Only households that had at least one child less than 60 months of age that farmed less than 15 hectares were eligible for selection (Bouis, 1991). Four detailed surveys were undertaken in these households at four month intervals beginning in Aug. '84 and ending in Aug. '85.

Study methodology. Heights and weights, information on food and non-food expenditures, morbidity, feeding practices for preschoolers, household income, farm production information and other details were surveyed. In addition, a detailed 24 hr recall was undertaken (see Bouis et al. 1992 and Rushton et al. 1994 for full details). Information was collected on foods prepared at the household level and information was also obtained on individual intakes of all family members.

Seasonal patterns of production. Bouis (1991) describes the crop patterns as follows: the first and fourth surveys rounds are carried out at the same time of year and coincide with the main corn harvest (July). At the start of the second round survey (November) a secondary corn harvest was just beginning. Although rainfall is spread relatively evenly throughout the year so that some corn was harvested by the households in each month of the 16 month survey, farmgate corn prices peaked at about 30% higher in real terms than the first round survey prices. Corn prices then declined in the fourth round. Sugar harvest peaked during the third round (March) although the sugar harvest is spread out over a 9 month milling season. There is relatively abundant sunshine during the period covered by the 3rd round surveys implying a lack of moisture for corn production. This raises the sugar content of the cane and makes for ideal harvesting conditions.

Table A. Brief tabulated summary of the four data sets used for re-analysis.

COUNTRY	LOCATION OF STUDY AREA	SOURCE	SAMPLE SIZE	METHODOLOGY	TIME OF YEAR/ SEASON	EXISTING VITAMIN A ANALYSIS	PREVALENCE OF VITAMIN A DEFICIENCY
Philippines	S. Bukidnon Province (rural area midway between two cities)	Dr Howarth Bouis, IFPRI, Washington	3000 individuals from 448 households	Detailed 24 hr recall	July '84, November '84, March '85, July '85) ie. every 4 months for 16 months	Seasonal household analysis of vitamin A intakes using old food composition tables, and conversion factor for B-carotene to RE of (1:2)	Nightblindness 0.9% in study area. 2nd worst region of the country. In Philippines 15.8% of 1-6 year olds had deficient plasma retinol.
Ghana	3 Rural villages (Slepor, Gidantuba, Nkwatanang)	Dr Elaine Ferguson, University of Guelph, Canada	148 children	3 Consecutive day weighed intake	Food shortage season (April-May) '89 and food plenty season (Nov-Dec) '89.	No analysis performed for vitamin A	In rural areas, low intakes of vitamin A intake have been observed
Malawi	1 Rural village (Chilunga)	Dr Elaine Ferguson, University of Guelph, Canada	65 children	3 Consecutive day weighed intake	Harvest (April) '86, post-harvest (July) '86, pre-harvest (November) '86	Seasonal vitamin A intakes using old food composition analysis	In rural areas, low intakes of vitamin A have been observed
Nepal	Salme, Nuwakot District (remote village)	Dr GJA Koppert, France	99 individuals from 31 families	4-7 Day weighed intake	March-May (Spring) '82, June-August (Monsoon) '82, September-November (late monsoon) '82, December-February (Winter) '83.	Seasonal vitamin A intakes using old food composition analysis	Widespread problem throughout the whole country

Existing vitamin A analysis of data set. Household vitamin A adequacy over survey rounds has been reported using old food composition analysis. This existing analysis cannot be compared to the present analysis due to the following differences: a B-carotene to RE conversion factor of 1:2 was used as opposed to the current recommended factors ie. 1:6 and 1:4 used in the present study; international units (IU) were used as opposed to the recommended units ie. ugRE used in the present study.

Prevalence of vitamin A deficiency. The prevalence of rate of nightblindness in the study area is 0.9% and plasma vitamin A of 6 month-6 year old children indicated that this region ranked 2nd among the 14 regions of the country in vitamin A deficiency (pers. comm. Food and Nutrition Research Institute, Philippines (FNRI) 1994). In addition, a survey by the FNRI institute in 1986 revealed that subjects from rural areas (such as the study area) had lower plasma deficiency than those from urban areas. Vitamin A deficiency was more prevalent in rural (18.8%) than in urban areas (8.4%). Also, about 20% of the children 6-11 months and 15.8% of 1-6 year old children (cut off 5%) had a deficient plasma retinol (< 10ug/dl)(pers. comm. FNRI).

2. and 3. Ghana and Malawi

Source. Dr Elaine Ferguson, Department of Family Studies, College of Family and Consumer Studies, University of Guelph, Ontario, Canada N1G 2W1.
For full details of the data set see Ferguson et al (1993).

Study area. The study took place in one rural village (Chilunga) in Southern Malawi and in three rural villages (Slepor, Gidantuba and Nkwatanang) in Ghana. All the villages had piped water except Nkwatanang, which was supplied by a river only.

Study population. Sixty-five rural children (29F, 36M; 62 +/-10 months; mean +/-SD) from one village in Malawi, and 148 rural children (83F, 65M; 59 +/-10 months) from three villages in Ghana participated in the survey. In both seasons, 81% of the children were surveyed.

Study methodology. The 3 consecutive day weighed intake method was used (including one market day, and one weekend day) and food intakes assessed over the seasons. Portion sizes using household measures were used where food was unintentionally consumed before weighing. Each child was asked to eat alone in order to quantify the amount consumed by each child.

Seasonal patterns of production. In Malawi, survey 1, 2 and 3 corresponded to the harvest (April), post-harvest (July) and pre-harvest (November) respectively. In Ghana, survey 1 and 2 corresponded to the food shortage season (April-May) and the season of food plenty (November-December) respectively. Some of the seasonal variation in the foods consumed in the study area reflected seasonal agricultural cropping patterns whereas for some (eg. purchased foods) the seasonal variation in the agricultural labour demands on the families or local food sellers was probably responsible. Seasonal differences were noted in the proportion of energy obtained from cereals (higher in food shortage season in Malawi and in the food plenty season in Slepor-the latter being due to tins of discarded fish being

collected and consumed), and legumes (lower in food shortage season in Malawi and Gidantuba).

Existing vitamin A analysis of data set. Only seasonal vitamin A intakes in Malawi using old food composition analysis have been analyzed and these will be documented in the results.

Prevalence of vitamin A deficiency. Ferguson et al. (1993) cite that in rural Malawi and Ghana, children often have low intakes of vitamin A.

4. Nepal

Source. Dr G.J.A. Koppert, Museum National D'Histoire Naturelle, Ecologie Generale, 4, Avenue du Petit Chateau, 91800 - Brunoy, France.
For full details of the data set see Koppert (1984, 1988) and Panter-Brick(1992).

Study area. The study was carried out in Salme, Nuwakot District, a remote village in a mountain area of Nepal. Two castes inhabit the village. Tamang households are largely self-sufficient, cultivating 5 cereal crops each year ie. maize, millet, wheat, barley, and paddy rice; and also tubers. Kami households obtain their staples from bartering implements manufactured by the men in the smithy or by working as day-labourers for which they are paid in grain. Although most of the families in the survey had some cattle the Tamang owned a sizeable herd whereas as the Kami kept only a few (only the Kami breed pigs). Food stuffs were seldom purchased outside Salme.

Study population. The families who participated in the survey were volunteers: random sampling was not carried out as friendly cooperation was more important for the study. The three groups distinguished for analysis were 1. village dwellers 2. Kami blacksmiths and 3. Goth dwellers who took care of the cattle. The Kami had more meat (though only 45g/head), the Goth dwellers had more milk (70g). For the others the diet was mainly vegetarian (pers. comm. G.J.A. Koppert).

Study methodology. At three monthly intervals over a period of one year all food consumption (with special attention given to snacks) of the 99 subjects (and the distribution of the cooked food among the household members) was measured by the 4 day weighed intake method. Up to 7 days food intake was measured if this was needed to get a good idea of the individual consumption of all the members of the family.

Seasonal pattern of production. The four periods covered by the survey were March-May (May to June is spring), June-August (monsoon season), September-November (September is late monsoon) 1982 and December-February 1983. Koppert (1984) explains the seasonal characteristics of the study area as follows: from March 1982-February 1983 the main cereals were available as follows: March-May-finger millet, millet/barley/wheat; June-August-wheat/barley/fresh maize/maize; September-November-maize/wheat ('food-for-work')/purchased rice; December-February-finger millet/maize rice/some maize. Of the total quantity of leafy vegetables, 41% is wild and 59% cultivated. From February to June no cultivated vegetables were available in the village: a welcome weed in the maize fields

appears around April. The cultivated leaves of the pumpkin and the bitter gourd can only be picked during and shortly after the monsoon; the most important and well appreciated radish leaves, during October-December. Of the cultivated leaves by frequency, 80% were fresh and 20% dried; of the wild leafy vegetables 98% were fresh and 2% were dried.

Existing vitamin A analysis of data set. Vitamin A intakes over seasons have been analyzed using old food composition tables and these results will be documented in the results.

Prevalence of vitamin A deficiency. The 1989 country profile for Nepal (ESN, 1989) reports that vitamin A deficiency is a significant health problem wide-spread through the whole country. The country profile states that risk factors of xerophthalmia include a previous history of diarrhoea, reduced consumption of vegetables and intermittent periods of food shortages, and low socio-economic status.

METHODS OF RE-ANALYSIS OF DATA SETS

Development of revised food composition tables of carotene analysis

For each of the 5 countries a list of foods consumed in the survey was obtained for the purpose of revising their carotene composition using where possible values obtained by HPLC or OCC methods of analysis. Due to the size of the Philippine data set the list contained all foods except those foods which provided a very small and insignificant contribution of carotene to the diets of the subjects. For the Ghanaian, Malawian and Nepalese data sets a list of all foods consumed in the survey was obtained.

Criteria used. Guidelines, developed by C. West, were used in order to select the best carotene analysis, obtained by using the HPLC or OCC methods, available for each food from the references West & Poortvliet (1993), Mangels et al. (1993) or Villard & Bates (1987). A revised value obtained by HPLC or OCC was considered for the food in question if the value belonged to a food which fulfilled to a large extent the following criteria: a) had the same scientific name; b) was the same variety/type of plant (often based on colour); c) was the same part of plant if stated or implied; d) was the same maturity of plant if stated or implied; e) had been exposed to the same extent of cooking and, if cooked, type of cooking; f) had the same moisture content (or a given value which could be adjusted). Preference was given to revised data from the same country/region unless it was more than one quality standard lower than that of new data from another region (the ranking of standards was set as follows: a, b, c and n with two steps to z; HPLC is one step higher than OCC data: see West & Poortvliet (1993) for explanation of the standards. Of these references the vast majority of revised values from HPLC or OCC analysis were obtained from the reference West & Poortvliet (1993).

In general if no suitable revised carotene analysis was available from the sources reporting HPLC or OCC data the following procedures were used. First, where foods were expected to contain low and sometimes moderate amounts of carotene, depending upon which revised value fitted the criteria more fully either the McCance & Widdowson reference and its

supplements (Holland et al. 1993, 1992a,b, 1991, 1989, 1988; Tan et al. 1985) which contained some HPLC analysis of foods (not stated for which foods specifically) or the Philippine Food Composition Tables (1990), original values used for the Nepal data set, or the food composition table for foods commonly eaten in East Africa (West 1987) for the Philippine, Nepal, and African data sets (Ghana, Malawi) respectively were used. Second, for remaining foods and for those foods expected to contain high and sometimes moderate amounts of carotene a value was estimated based on the HPLC or OCC values of similar foods; if the food was a composite dish a revised value was estimated from the raw ingredients it contained.

For the Philippine data set retinol equivalent values for all foods except those supplying an insignificant amount of retinol were changed from the existing 1980 Philippine food composition values to the 1990 Philippine food composition values. For the African data sets no original carotene and retinol values were available and therefore either the McCance & Widdowson's reference and its supplements (Holland et al. 1993, 1992a,b, 1991, 1989, 1988; Tan et al. 1985) or the reference West (1987) were used to obtain retinol equivalents.

Re-analysis of selected data

1. Philippine data set

Subjects. 1-3 year olds n=1339(excluding those breastfeeding), 4-6 year olds n=1675and all ages as a group n=10765.

Methods. Analysis of group means of carotene (ug) and vitamin A (ug RE) of the single detailed 24 hr recall/subject employed in the Philippine study over seasons were carried out. It is generally agreed that for large groups of subjects single well conducted 24 hr recalls provide estimates of group average intakes that are comparable to those obtained with more cumbersome techniques (Beaton et al. 1979; and others). However, researchers (Willet, 1990; Beaton, 1983) have suggested that reporting on the distribution of the group intake based on one 24 hr recall would be extremely misleading as this would be seriously distorted due to extreme values that are higher and lower than any of the true long-term averages for any subject. Distributions showed that the Philippine vitamin A intake data was positively skewed. However, any transformation of the data would give a falsely lower group mean value (as group analysis of the single recall results in an expectedly large variation). Due to lack of references documenting whether transformation of group data based on single recalls should be carried out it was decided to present both log-transformed and untransformed data. Where absolute values alone were of interest in order to make assumptions about adequacy, arithmetic means have been presented.

The oneway analysis of variance Tukeyb test was used to test for a difference between both arithmetic and geometric group means. Although analysis of variance assumes a normal distribution the test gives good results even if the normality assumption does not quite hold (Norusis, 1990). The Z-test was used to compare two group means. Statistics were calculated using the statistical package SPSS-PC version 4 (Norusis, 1988).

2. and 3. Ghana and Malawi data set

Subjects. Ghana: n=75preschool children; Malawi: n=51preschool children

Methods. Both data sets showed a skewed distribution. Analysis of median, 1st and 3rd quartile intakes of carotene (ugRE) and vitamin A (ugRE) obtained by the 3 day weighed intake of individuals method was carried out over seasons, by selected food groups and by meal type over seasons using the non-parametric Wilcoxon signed rank test. All statistics were calculated using the statistical package SYSTAT (Wilkinson, 1990).

4. Nepal data set

Subjects. 99 individuals of all ages.

Methods. Arithmetic mean intakes of carotene (ug), retinol (ug) and vitamin A (ugRE) obtained from the 4-7 day weighed intake of individuals method were calculated by season, age group and dwelling. The Z-test was used to determine the significance of the difference between the means over the seasons.

RESULTS

1. Philippine data set

Table 1 shows the arithmetic and geometric means of carotene intake (ug) for the all-ages group before and after revising the food composition table for carotene. The differences between results using both the arithmetic and geometric means is highly statistically significant ($P<0.001$).Using the revised composition table the arithmetic means show a carotene intake (ug) for all subjects as a whole which was reduced by 44% (the geometric mean shows a reduction of 32%). All subsequent analysis was carried out on results obtained using the revised food composition values.

Fig. 1 a,b,c shows the distributions of the group intakes of carotene (ug) in RE for the all-ages group, 1-3 year olds and 4-6 year olds over the survey rounds. There is an expected artificially high standard deviation ie. the tails of the distribution have been broadened, due to only one 24 hr recall per person in each round being measured. The percentage of subjects above and below certain cut-offs cannot be discussed and only the group mean can be statistically compared. There is a strong reduction in the tail of the distribution as the survey proceeds from rounds 1 to 4 for the all-ages group, the 1-3 year group and 4-6 year group indicating reduced variation in quantity of carotene consumed as the survey proceeds. Table 2 shows that both the arithmetic and geometric means of carotene intake (ugRE) for the all-ages group, 1-3 year olds and 4-6 year olds is highest in round one and this decreases progressively over the survey rounds from 1-4. At the individual level Morgan et al. (cited by Willett, 1990) also observed that those with higher mean intakes have greater within-person variation. As the sample size was large, the survey well-designed and well-conducted, and the same trends were apparent in different age groups, it is unlikely

Table 1. Arithmetic and geometric means of carotene (ug) for all ages (n= 10765) before and after revising the food composition database for carotene.

REVISED FOOD COMPOSITION DATABASE	OLD FOOD COMPOSITION DATABASE
Carotene intake (ug)	
Arithmetic mean (SD) (Geometric mean (SD))	Arithmetic mean (SD) (Geometric mean (SD))
1192 (2400)* (51 (5.6))*	2114 (5090) (75 (6.7))

* Values significantly different from those obtained using old food composition database: Z test, P=<0.00003.

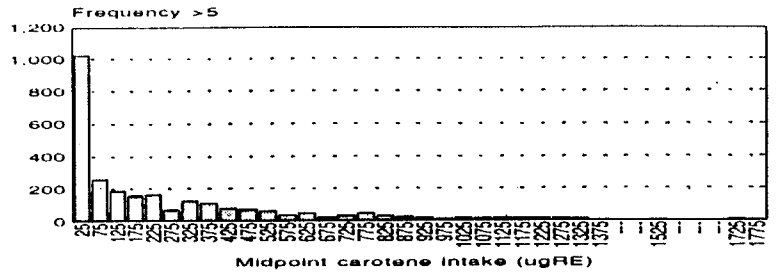
Table 2. Arithmetic and geometric means of carotene (ugRE) for all age groups, 1-3 year olds and 4-6 year olds over survey rounds.

	ALL AGES GROUP		1-3 YR OLDS		4-6 YR OLDS	
SURVEY ROUND	arith. mean (SD) (geom. mean (SD))	n	arith. mean (SD) (geom. mean (SD))	n	arith. mean (SD) geom. mean (SD)	n
1	313*** (485) (84*** (6.4))	2797	158*** (281) (31*** (7.0))	390	213*** (371) (56*** (5.7))	382
2	210** (437) (55** (5.6))	2677	112* (225) (22* (6.4))	336	155** (294) (33* (6.0))	399
3	156* (367) (44* (4.7))	2632	76 (253) (18 (4.6))	312	98 (210) (28 (4.6))	396
4	109 (228) (33 (4.7))	2659	51 (104) (14 (4.4))	301	70 (124) (22 (4.4))	403

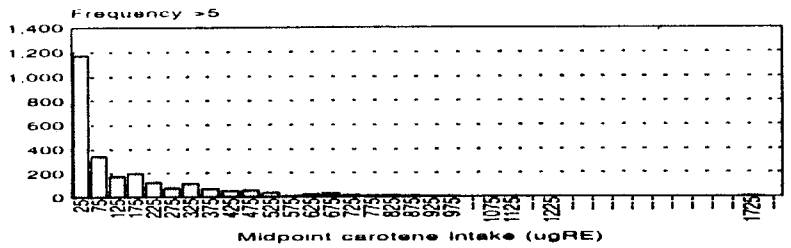
*** Values significantly different to survey rounds 2, 3 and 4: oneway anova (tukeyb test), P=<0.05.
** Values significantly different to survey rounds 3 and 4: oneway anova (tukeyb test), P=<0.05.
* Values significantly different to survey rounds 4: oneway anova (tukeyb test), P=<0.05.

Fig. 1a. Distributions of carotene intake (ugRE) for the all ages group

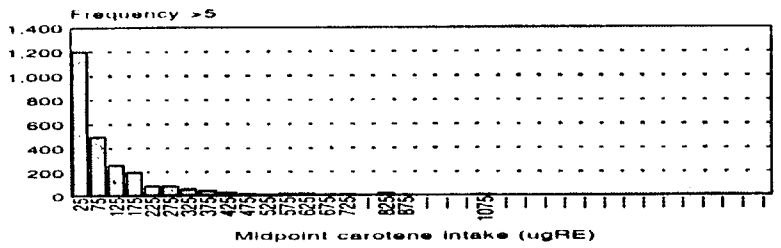
Round 1 (n=2747)



Round 2 (n=2677)



Round 3 (n=2632)



Round 4 (n=2659)

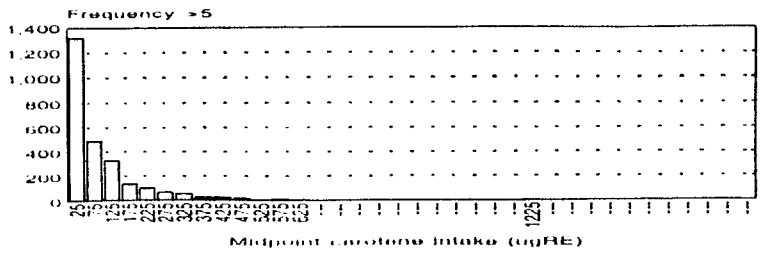
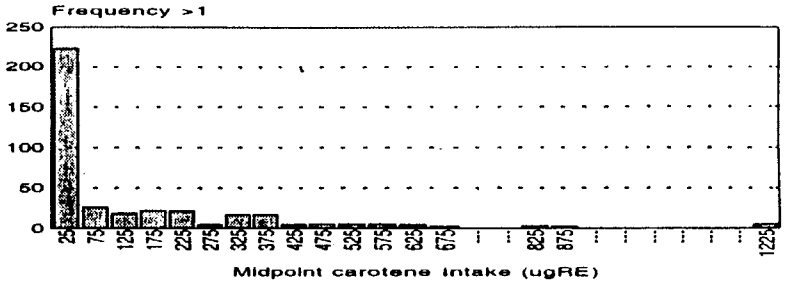
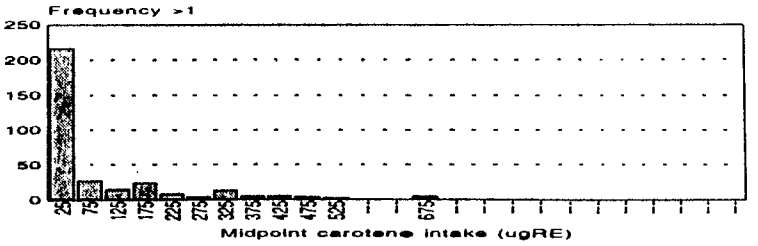


Fig. 1b. Distributions of carotene intake (ugRE) for 1-3 year olds

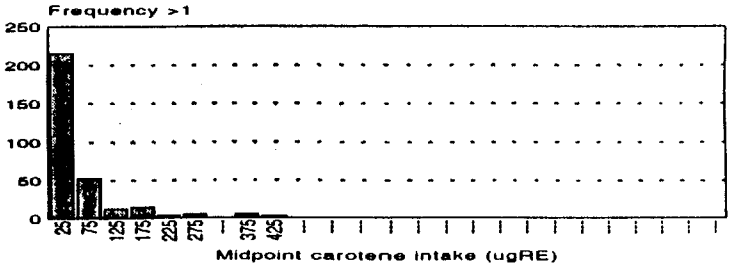
Round 1 (n=350)



Round 2 (n=336)



Round 3 (n=312)



Round 4 (n=301)

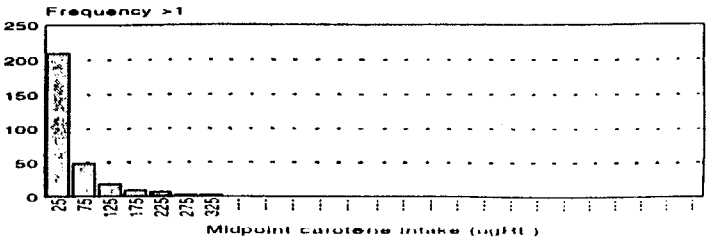
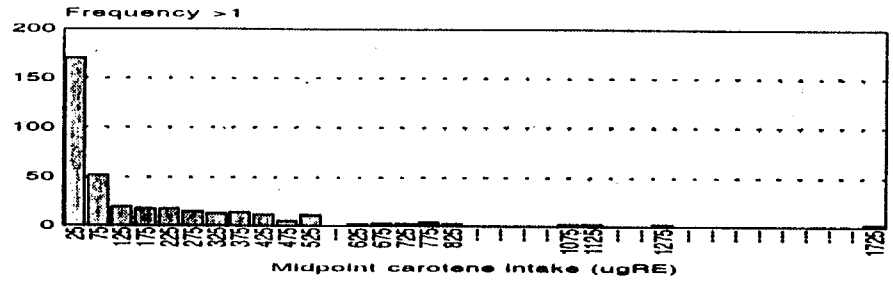
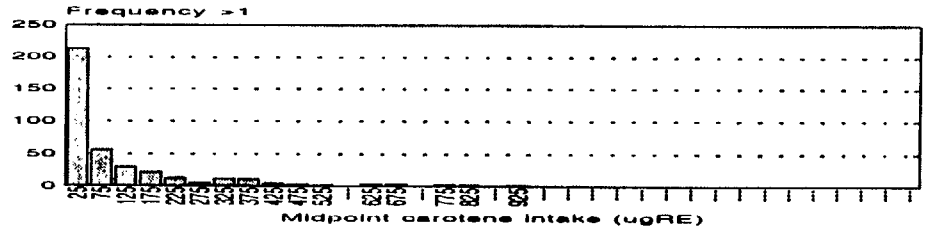


Fig. 1c. Distributions of carotene intake (ugRE) for 4-6 year olds

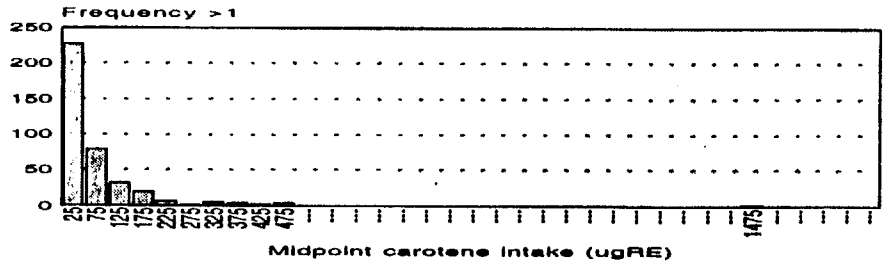
Round 1 (n=382)



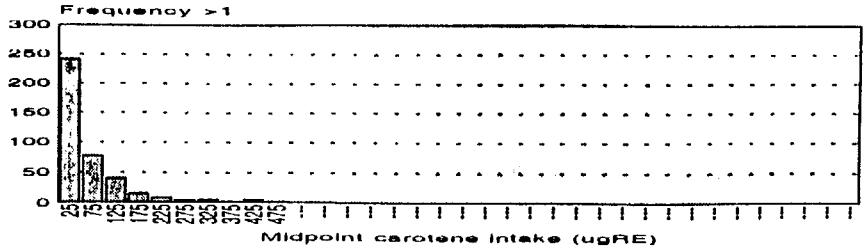
Round 2 (n=399)



Round 3 (n=396)



Round 4 (n=403)



that both the reduced intake and variation in intakes as the survey proceeds could be explained either by the effect of experience and improvement in measurement, or by respondent and enumerator fatigue. If the all-ages group is considered the means as the survey proceeds are all statistically different. For both ages 1-3 years and 4-6 years, round 1 shows significantly different results to all other rounds; for round 2 the 1-3 year age group and the geometric mean for the 4-6 year group shows round 2 to be significantly different to round 4 but not significantly different to round 3. Again for the 1-3 year group and 4-6 year group, rounds 3 and 4 are not significantly different to each other. This may indicate that the younger age groups are more protected from changes in carotene intake over time.

The survey rounds span a period of one year and it may be expected that mean intakes would be similar in round 1 (July '84) and round 4 (July '85) the season which coincides with the main corn harvest (Bouis, 1991). Due to the relatively even distribution of rainfall throughout the year in the study area and its position outside the path of typhoons this area is better situated than others in the Philippines for realizing rapid increases in agricultural production (Bouis & Haddad, 1990). It may also be possible that due to agricultural commercialization in the study area and increased export crop production that intake of macro and micro nutrients may not follow seasonal trends of production in the study area; it may depend more on the extent of exportation of crops (and hence prices in the study area), which rely on seasonality, economic and social conditions in other areas of the country. Nutritional intake in the study area may therefore be more reliant on prices in the study area of the major sources of these nutrients and incomes of the households. Table 5 gives the availability and prices of selected vegetables during the four survey rounds. Not only have prices risen, but own production fell sharply between rounds 1 and 4. This suggests that commercial agriculture has at least partly displaced local horticulture, thereby reducing the supply of at least some of the best sources of carotene in the area. A more in-depth examination of the role and impact of commercialisation of agriculture would be needed to properly explain the fall in carotene intakes between 1984 and 1985. It could also be inferred that in order to study seasonal trends of intakes more than one year of surveying is necessary. This is however not likely to be practical for large scale population surveys. Even with the absence of a cyclical pattern of carotene intake time trends over the 16 months and their relation to availability and prices in the study area can be discussed and recommendations to help improve vitamin A intake made based on the existing trends.

In order to look at seasonality/time trends more closely in 1-6 year olds Fig. 2 a-f, Table 3 a,b, Table 4 a,b and Table 5 are presented. Fig. 2 a-f and Table 3 a,b shows the arithmetic and geometric mean intakes of carotene (ugRE) for the all ages group, 1-3 year olds and 4-6 year olds by expenditure quintile[1] and by survey round. The arithmetic means show expenditure quintile 5 in age group 1-3 years has no two survey rounds which are statistically significantly different. In all other quintiles for the all-ages group, 1-3 years and 4-6 years the arithmetic mean intakes in at least one survey round are statistically different to at least one other survey round. Geometric means show in ages 1-3 years olds that no two survey rounds in expenditure quintiles 3, 4 and 5 are statistically significantly different.

[1] The expenditure quintile (or proxy for income) is derived from total household expenditure itemized for the previous four months using a variable time period recall method for items purchased more frequently than once a month (for food expenditures) or once every four months (for non-food expenditures). Expenditure quintile 1 is the lowest rank and 5 is the highest.

Fig 2a Arithmetic means of carotene intake (ugRE) for 1-3 year olds by expenditure + survey round

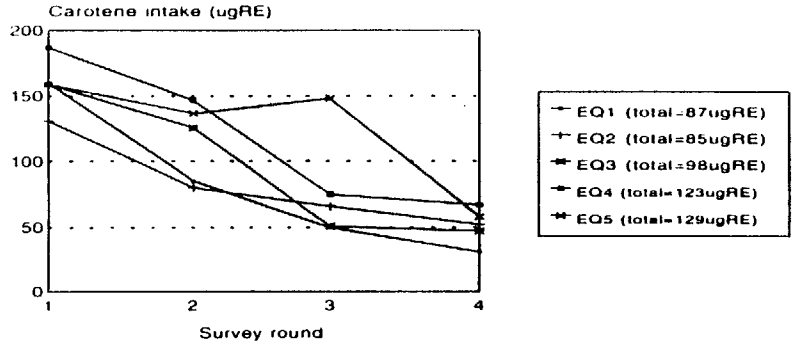


Fig 2b Arithmetic means of carotene intake (ugRE) for 4-6 year olds by expenditure + survey round

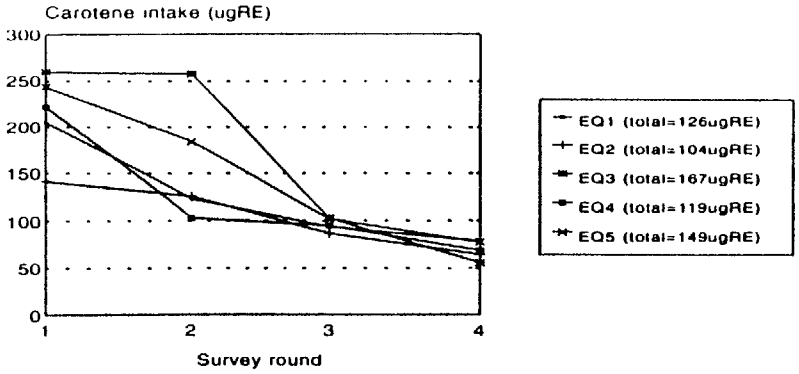


Fig 2c Arithmetic means of carotene intake (ugRE) for all age groups by expenditure + survey round

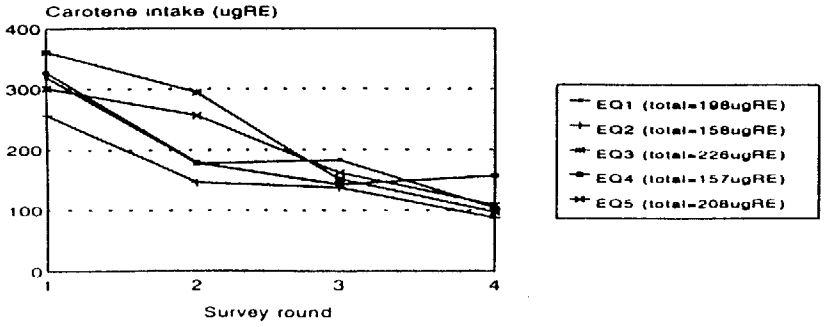


Fig 2d Geometric means of carotene intake (ugRE) for 1-3 year olds by expenditure + survey round

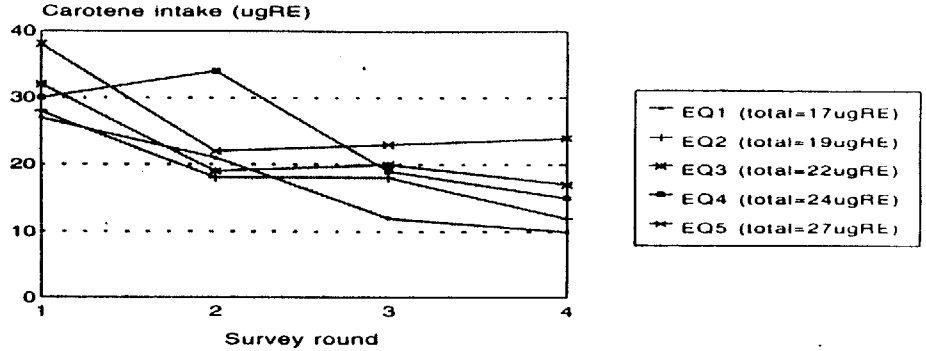


Fig. 2e Geometric means of carotene intake (ugRE) for 4-6 year olds by expenditure + survey round

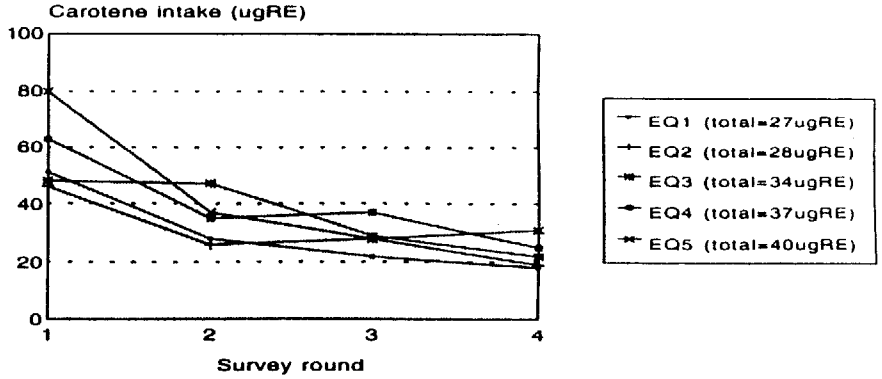


Fig. 2f Geometric means of carotene intake (ugRE) for all ages by expenditure + survey round

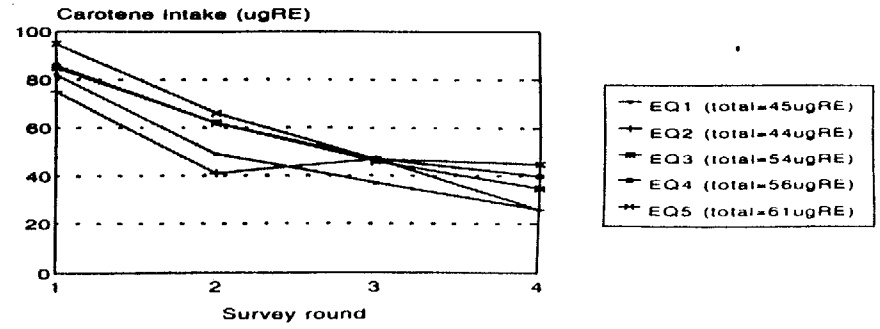


Table 3a. Arithmetic means of carotene intake (ugRE) for 1-3 year olds, 4-6 year olds and the all ages group by expenditure quintile and survey round

	EXPENDITURE QUINTILE				
	1	2	3	4	5
	Arithmetic mean carotene intake (ugRE)				
ROUND	1-3 year age group				
1	160***	131*	159**	187*	159
2	85	80	126	147	137
3	50	66	51	75	148
4	31	52	47	67	58
	4-6 year age group				
1	205***	141*	260	222***	244**
2	123	126	258*	103	184
3	94	87	103	95	102
4	79	65	56	69	78
	All ages group				
1	319***	257***	361**	327***	301**
2	178*	146*	294**	179	257**
3	183*	137*	151	142	162
4	103	87	97	157	108

* Statistically significant to round 4: P=<0.05; ** statistically significant to rounds 3,4: P=<0.05; *** statistically significant to rounds 2,3,4: P=<0.05.

Table 3b. Geometric means of carotene intake (ugRE) for 1-3 year olds, 4-6 year olds and the all ages group by expenditure quintile and survey round

	EXPENDITURE QUINTILE				
	1	2	3	4	5
	Geometric mean carotene intake (ugRE)				
ROUND	1-3 year age group				
1	27**	28*	32	30	38
2	21	18	19	34	22
3	12	18	20	19	23
4	10	12	17	15	24
	4-6 year age group				
1	51**	46*	48	63*	80***
2	28	26	47*	35	37
3	22	28	29	37	28
4	18	19	22	25	31
	All ages group				
1	82***	75***	85***	86***	95***
2	49**	41*	62**	62**	66**
3	37*	47*	46*	47	47
4	26	26	35	40	45

* Statistically significant to round 4: P=<0.05; ** statistically significant to rounds 3,4: P=<0.05; *** statistically significant to rounds 2,3,4: P=<0.05.

Table 4a. Major sources of carotene by survey round and expenditure quintile for 1-3 year olds.

	EXPENDITURE QUINTILE				
SURVEY ROUND	1	2	3	4	5
1	5.4g horse radish leaves 9.1g sweet potato leaves/tops 14.8g sweet potato yellow	5.4g horse radish leaves 4.8g sweet potato leaves/tops 9.0g sweet potato yellow	23.2g sweet potato yellow 4.4g horse radish leaves 8.3g sweet potato leaves/tops	14.3g sweet potato leaves/tops 4.4g horse radish leaves 4.3g lupo leaves	5.8g horse radish leaves 8.7g sweet potato leaves/tops 2.4g lakiway leaves
2	2.5g horse radish leaves 9.7g sweet potato yellow 2.5g sweet potato leaves/tops	5.5g horse radish leaves 2.2g sweet potato leaves/tops 32.7g banana unripe 'Cavendish'	6.4g horse radish leaves 17.3g sweet potato yellow 25.4g banana unripe 'Cavendish'	9.0g horse radish leaves 12.2g sweet potato yellow 3.8g sweet potato leaves/tops	8.4g horse radish leaves 12.7g sweet potato yellow 1.1g sweet potato leaves/tops
3	5.3g chicken stew 0.78g horse radish leaves 1.6g sari-sari utan binas-oy	1.9g horse radish leaves 4.0g chicken stew 9.3g mango green ripe	1.6g horse radish leaves 1.8g sweet potato leaves/tops 3.2g squash young leaves	11.3g sweet potato yellow 5.9g chicken stew 1.9g sweet potato leaves/tops	4.9g cassava tuber leaves 4.0g chicken stew 1.1g horse radish leaves
4	1.4g horse radish leaves 0.92g sweet potato leaves/tops 5.9g squash fruit	2.3g horse radish leaves 0.66g cassava tuber leaves/tops boiled 0.69g sweet potato leaves/tops	1.1g horse radish leaves 1.0g sweet potato leaves/tops 3.0g papaya medium ripe	11.5g sweet potato yellow 1.6g sweet potato leaves/tops 0.45g carrot	1.9g horse radish leaves 0.89g sweet potato leaves/tops 5.8g squash fruit

Table 4b. Major sources of carotene by survey round and expenditure quintile for 4-6 year olds

	EXPENDITURE QUINTILE				
SURVEY ROUND	1	2	3	4	5
1	6.2g horse radish leaves 11.8g sweet potato leaves/tops 2.9g purslane	7.5g horse radish leaves 4.5g sweet potato leaves/tops 1.8g sweet potato leaves/tops purple	51.7g sweet potato yellow 8.8g horse radish leaves 6.3g sweet potato leaves/tops	8.5g horse radish leaves 10.9g sweet potato leaves/tops 13.1g sweet potato yellow boiled	17.8g sweet potato leaves/tops 5.4g horse radish leaves 17.8g sweet potato yellow
2	4.2g horse radish leaves 4.2g sweet potato leaves/tops 49.2g banana unripe 'Cavendish'	8.1g horse radish leaves 4.4g sweet potato leaves/tops 56.1g banana unripe 'Cavenish'	3.9g cassava tuber leaves/tops boiled 29.1g sweet potato yellow 6.0g horse radish leaves	3.9g horse radish leaves 43.4g banana unripe 'Cavendish' 2.5g sweet potato leaves/tops	8.8g horse radish leaves 32.3g sweet potato yellow 2.0g sweet potato leaves/tops
3	14.5g sweet potato yellow 6.2g chicken stew 1.3g horse radish leaves	4.1g horse radish leaves 2.7g sweet potato leaves/tops 1.7g swamp cabbage	12.6g sweet potato yellow 1.7g horse radish leaves 2.7g sweet potato leaves/tops	12.7g sweet potato yellow 4.8g chicken stew 1.6g horse radish leaves	12.5g sweet potato yellow 2.3g purslane 0.99g horse radish leaves
4	9.8g sweet potato yellow 1.8g horse radish leaves 0.63g cassava tuber leaves/tops boiled	2.4g horse radish leaves 0.55g cassava tuber leaves/tops boiled 1.5g sweet potato leaves/tops	1.4g horse radish leaves 1.5g sweet potato leaves/tops 3.2g sweet potato yellow	1.6g horse radish leaves 7.1g sweet potato yellow 0.66g carrot	2.8g horse radish leaves 1.8g sweet potato leaves/tops 0.62g jute leaves

Table 5. Vegetable availability and prices by survey round by source.

SURVEY NO.	TOTAL	PURCHASED	OWN-PRODUCED	GIFTS	PRICE
.....grams per capita per week..... per kg					
Sweet potato tops or leaves (Kamote Tops)					
1	52.0	1.5	42.8	5.7	4.22
2	22.8	1.0	19.2	2.6	8.71
3	25.7	0.8	23.0	1.9	8.19
4	14.6	0.7	12.4	1.5	7.77
Swamp cabbage (Kangkong)					
1	17.6	0.7	13.2	3.6	4.45
2	6.2	0.2	4.2	1.0	5.81
3	13.0	0.7	7.7	3.0	5.67
4	6.5	1.0	3.9	1.4	5.97
Horse radish tree leaves (Mulungay)					
1	12.0	4.1	7.4	0.5	28.90
2	26.4	11.1	13.6	1.5	7.34
3	8.5	4.5	3.4	0.6	22.06
4	19.2	7.5	10.6	1.0	14.60
Other leafy green vegetables					
1	42.7	10.9	29.4	2.4	6.04
2	14.9	4.4	9.6	0.8	11.41
3	21.1	5.6	12.9	2.5	11.79
4	22.3	3.1	17.6	1.4	8.72
All other vegetables					
1	429.8	168.0	218.7	42.2	3.29
2	262.6	103.5	133.7	24.0	4.32
3	307.8	166.3	113.0	26.4	4.48
4	366.2	161.1	169.2	34.9	3.99
All vegetables					
1	554.2	185.1	311.7	54.4	3.65
2	332.9	120.2	180.3	30.0	5.05
3	376.1	177.9	160.0	34.4	5.17
4	428.7	173.5	213.8	40.4	4.55

Source: Food Expenditure Survey (Bouis, 1991).

Geometric means also show that in the 4-6 year old age group expenditure quintiles 2, 3 and 4 (2, 3 and 5 if arithmetic means considered) show a slightly reduced variation in carotene intake over the survey rounds. Similarly, if the all-ages group is considered expenditure quintiles 2, 4 and 5 (geometric means) and 3, 4 and 5 (arithmetic means) show a slightly reduced variation in intake over time. These findings may indicate that the higher expenditure quintiles of the 1-3 year group and to some extent for the all-ages group and 4-6 year age groups are more protected against changes in carotene over time. As with Table 2, Fig 2 and Tables 3 a,b also shows it is the younger age groups especially the 1-3 year age group who may be more protected against changes in intake of carotene over time. With regard to the totals for each expenditure quintile and different age groups in Fig 2a-f if arithmetic means are considered, intakes of carotene for only the 1-3 year old age group appear to be positively correlated with expenditure quintile. However, geometric means show that for all groups ie. the all-ages group, the 1-3 year group and the 4-6 year group, total carotene intake is positively correlated with expenditure quintile.

Table 4 a,b shows the major sources of carotene intake for 1-3 year olds and 4-6 year olds by survey round and expenditure quintile. Both geometric and arithmetic results gave the same major sources of carotene. Quantities of food sources are calculated from arithmetic values and they refer to average intake over the number of subjects per day. In general horse radish leaves, sweet potato and sweet potato leaves/tops appear by far as the major sources of carotene in the diets of children aged 1-6 years old. Other green leafy vegetables, unripe 'Cavendish' bananas, ripe mangoes, squash fruit, carrot, medium ripe papaya and composite dishes composed the other major sources of carotene. Canned chicken stew and a local dish containing leafy vegetables is eaten by 1-6 year olds only in round 3. The revision of the food composition database had a small and perhaps important effect on changing the major sources of carotene. The table is replicated using the old food composition database for carotene for 1-3 year olds (see Appendix 1).

Consumption of fruits by children is always difficult to assess accurately; fruits are often forgotten because they may be eaten between meals, or consumption is underestimated because the child has eaten the fruit outside the home, possibly from a tree and most likely away from the mother. This is especially likely among older children. While Tables 4a and 4b include a few fruits (mangos, papayas), it is very likely that more were consumed than recorded. This could lead to a substantial underestimate of carotene intake, particularly for example during the mango season. However, West's food composition tables do indicate a much higher carotene content in green leaves than in fruit[2].

Table 5 is reproduced from the reference (Bouis, 1991) and shows vegetable availability and prices by survey round by source. For the age group 1-3 years as the price of horse radish leaves changes over the survey rounds Table 4a shows for all expenditure quintiles except quintile 1 that consumption of these foods reflects the price changes and also to some extent, the amount purchased or own-produced. A similar effect but opposite pattern is generally seen for all expenditure quintiles for sweet potato tops or leaves. Table 4b shows that for the age group 4-6 years these effects of availability and price changes for horse radish generally occurs only in expenditure 2 and 5 but for sweet potato leaves/tops occurs for all expenditure quintiles. The pattern is much clearer for rounds 1 and 2 where

[2]Studies conducted after the preparation of the draft version of this report do however suggest that absorption of carotene from green leaves may be much lower than originally supposed.

fluctuations in price changes of these sources is more profound. The intakes of major sources of carotene therefore appear in general to be associated to availability and prices of these foods for the 1-3 years group and to a lesser extent also for the 4-6 year group, especially in rounds 1 and 2 as the fluctuations are greater.

The progressively declining carotene intakes for all subject groups can perhaps be explained by the availability and price changes over the survey rounds. For rounds 1 and 2 the prices of the major sources of carotene namely horse radish leaves and sweet potato leaves/tops oppose each other meaning at least one major source is cheap in rounds 1 and 2. For rounds 3 prices of these major sources are both high and these fall only slightly in round 4 meaning that carotene intakes are likely to fall as the major sources are expensive. When the prices of the 2 major sources of carotene are both high, ie. in rounds 3 and 4, various other sources of carotene appear in the list of major sources for which the availability and price data is not shown specifically. However, Table 5 shows that the price of other green leafy vegetables, all other vegetables and all vegetables is also highest in round 3 and these prices remain relatively high in the 4th survey round.

The FAO (1988) requirements have been used to assess adequacy of vitamin A intakes of the study population. Table 6 shows the estimated requirements for vitamin A for all age groups. The basal requirement is defined as the minimum daily intake of vitamin A, expressed as retinol, to prevent the appearance of clinical signs of vitamin A deficiency (night blindness and epithelial lesions of the conjunctiva and cornea of the eye); and to permit normal growth. The safe level of intake refers to the normative storage requirement +2 SD. The normative requirement is defined as the average continuing intake of vitamin A required to permit adequate growth and other vitamin A dependent functions and to maintain an acceptable total body reserve of the vitamin. Thus based on age and nutritional status, the requirements for Filipino children was considered to be 200-217ugRE/d for the basal requirement and 300ugRE/d for the safe level of intake.

It was considered in the preparatory stages of the project that it may be possible that the basal and safe level of requirements would be lower as children's requirements are known to be estimated from intake studies of infants and adults. Since on revising the food composition tables for carotene the results of intake studies are approximately 50% lower (pers. comm. C. West) it was thought that this may also mean the estimated requirements would need to be reduced. However, these intake studies used for estimating requirements were based on breast milk intakes of infants and on an oral dose of retinol for adult assessment. As the accuracy of methods of retinol analysis is generally not in question, it can be assumed that the recommended requirements of vitamin A are valid.

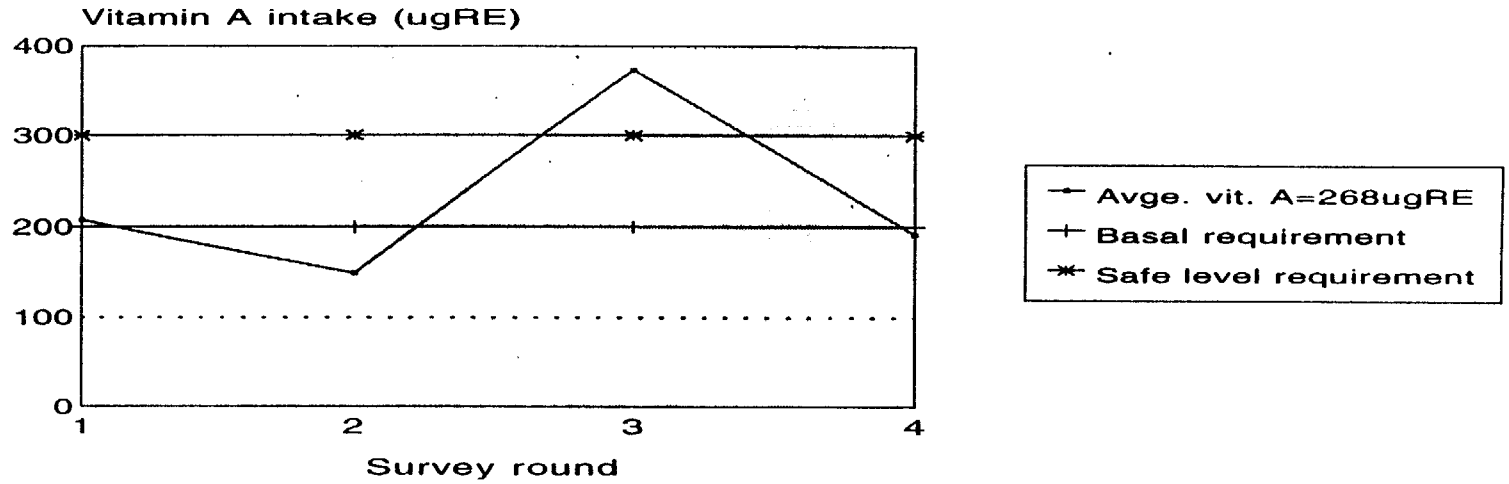
The commonly used conversion factor (and that developed by FAO/WHO) for converting B-carotene equivalents into retinol is 6:1. However, Reddy (1988) in the reference 'vitamin A requirements for Indians' challenge this factor and recommended a factor for the Indian population of 4:1 based on a carotene absorption of 50% as opposed to 33% (Reddy, 1988). They suggest that carotene absorption may be even higher than 50% if vitamin A intakes are below recommended levels. As intakes in the study area are low, both Fig. 3a,b, Fig. 4a,b are presented which show arithmetic mean intakes for age groups 1-3 and 4-6 years respectively using both the conversion factor 1:6 and 1:4. It can be seen from Figs 3 and 4 that the vitamin A intakes (ugRE) appear to fluctuate over the year and fall both over and under the basal and recommended (safe) requirement level. Although the fluctuations in

Table 6. Estimated requirements for vitamin A (ug retinol equivalents per day).

GROUP	AGE (YEARS)	BASAL REQ. (Incl. variability)	SAFE LEVEL OF INTAKE
Both sexes	0-1	180	350
	1-6	200	400
	6-10	250	400
	10-12	300	500
	12-15	350	600
Boys	15-18	400	600
Girls	15-18	330	500
Men	18+	300	600
Women	18+	270	500
Pregnant women		370	600
Lactating women		450	850

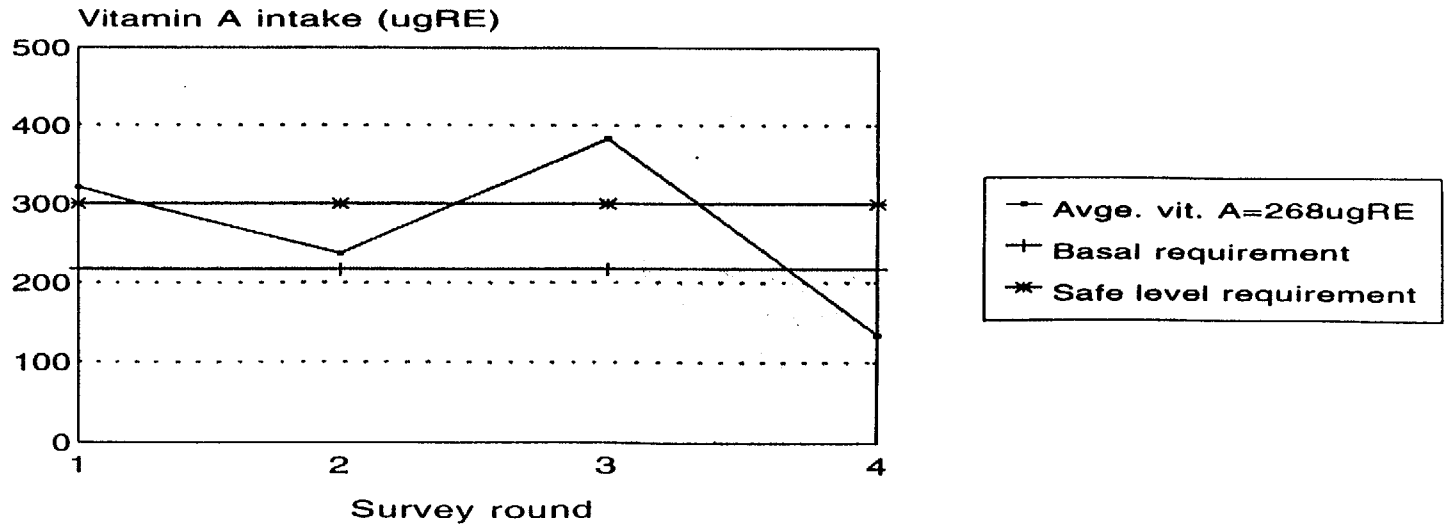
Source: FAO (1988)

Fig. 3a Vitamin A intake (ugRE) of 1-3 year olds using B-carotene to retinol conversion factor 1:6
(n=1339 total cases over 4 rounds)



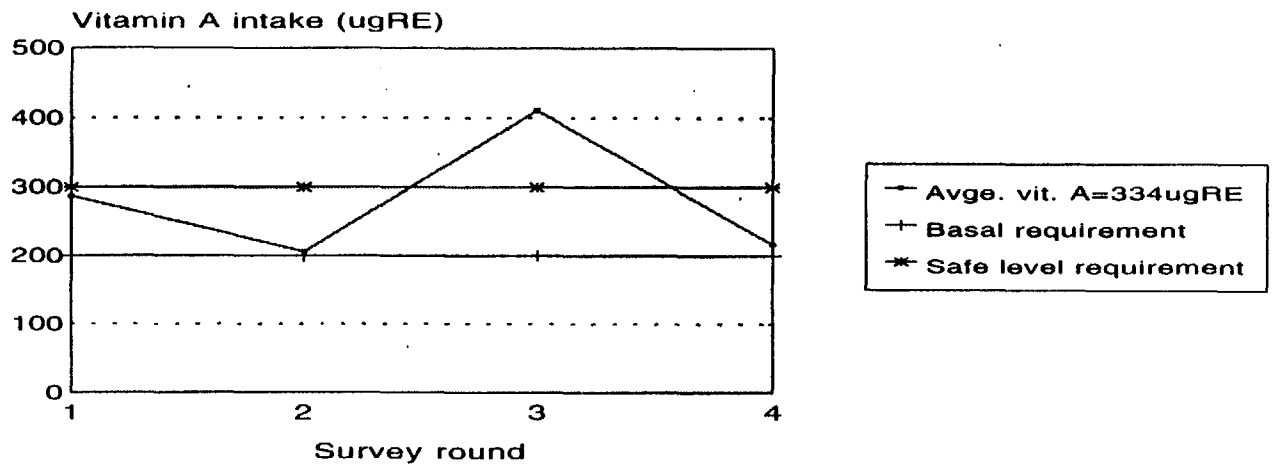
Z test: rounds 1 and 2 sig.diff P<0.05; Tukeyb test: no 2 rounds sig.diff.

Fig. 3b Vitamin A intake (ugRE) of 4-6 year olds using B-carotene to retinol conversion factor 1:6
(n=1580 total cases over 4 rounds)



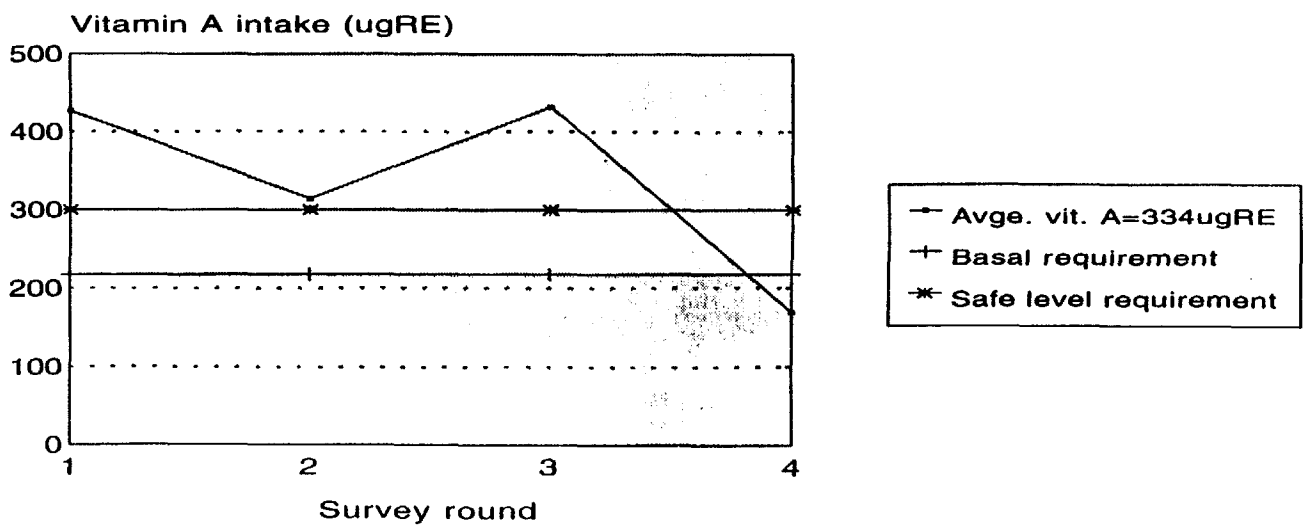
Z test: rounds 1 and 2, 3 and 4, 2 and 4 sig.diff P<0.05; Tukeyb test: no 2 rounds sig.diff.

Fig. 4a Vitamin A intake (ugRE) of 1-3 year olds using B-carotene to retinol conversion factor 1:4
(n=1339 total cases over 4 rounds)



Z test: rounds 1 and 2 sig.diff P<0.05; Tukeyb test: no 2 rounds sig.diff.

Fig. 4b Vitamin A intake (ugRE) of 4-6 year olds using B-carotene to retinol conversion factor 1:4
(n=1580 total cases over 4 rounds)



Z test: rounds 1 and 2, 3 and 4, 1 and 4 sig.diff P<0.05; Tukeyb test: rounds 1 and 4 sig.diff P<.05

intake appear to be fairly strong the tukeyb test and the z-test show for the 1-3 year olds that vitamin A intake over survey rounds is only significantly different between survey rounds 1 and 2. For the 4-6 year olds vitamin A mean intakes in all survey rounds are significantly different except for the difference between rounds 2 and 3. Thus what appears to be a large increase in intake in retinol from rounds 2 to 3 for both age groups is not statistically different due to the very large SD ie. variation in intake (due to retinol) around the mean. Table 7 a,b shows the major sources of retinol in the diets of 1-3 year old and 4-6 year old children. It could be that the canned chicken stew which occurs almost exclusively in round 3 especially for the lower expenditure quintiles may be the cause of this high variability. It is not clear why canned chicken stew should appear almost exclusively in round 3 and be the major source of retinol for many expenditure levels in both age groups. The existing data set originally contained food composition values for retinol from the 1980 Philippine food composition tables. The retinol value for canned chicken stew in the 1980 and 1990 Philippine food composition tables was 4305 ugRE and 240 ugRE respectively. Large changes in retinol content of some fish commonly consumed were also observed. Such large changes made it necessary to revise the retinol values in the database using the 1990 Philippine tables and this also shows the importance of using the most accurate food composition data available for all nutrients. The 1990 Philippine food composition table values for retinol resulted in an approximate decrease of 10ug RE vitamin A intake for each age group using both the 1:6 and 1:4 conversion factors.

Times during the year where group mean intakes are below 200ugRE (for 1-3 yr olds) or 217ugRE/d (for 4-6 yr olds) may give cause for great concern unless intakes throughout the rest of the year have been sufficient to build up stores of vitamin A in the body. The average intakes over all survey rounds for each age group (see Figs 3 and 4) shows that (except for the 4-6 year olds if the conversion of B-carotene equivalents to retinol is 1:4), all values are below the 300ugRE/d safe requirement. Although the yearly averages are all above the 200ugRE/d and 217ugRE/d for 1-3 and 4-6 year olds respectively this may not mean that the basal requirements throughout the year are met. The storage efficiency of vitamin A is assumed to be 20% (this actually varies from 20-80% in various studies) (Olson, 1978) or 50% (reported values 40-90%) (Dept. of Health, 1992). Fig. 3a,b shows it is therefore likely (if a B-carotene equivalent conversion factor of 1:6 is considered) that for the group as a whole there will be insufficient intakes in the periods where intakes are higher than the basal requirements to increase vitamin A storage in tissues to be utilized in periods when intake is less than the basal requirement. Figs 4a,b show for the 4-6 year group as a whole that if a 1:4 conversion factor is used, enough vitamin A can be stored in survey round 3 to enable basal requirements to be met in round 4.

2. and 3. Ghana and Malawi data set

Table 8 shows the seasonal daily intakes of carotene (ugRE), total vitamin A (ugRE) (using both new and old composition tables for carotene) and Non-Starch Polysaccharides (NSP) (g) of Malawian preschool children. It can be seen that total vitamin A intake over the year using the revised carotene values results in a 42% reduction in intake compared to those from the old food composition tables. The results using the revised carotene analysis show significant differences in carotene and vitamin A intake, and also NSP intakes, between surveys 2 and 3 (ie. post harvest and preharvest). Although Table 9 shows a significant

Table 7a. Major sources of retinol by survey round and expenditure quintile for 1-3 year olds.

	EXPENDITURE QUINTILE				
SURVEY ROUND	1	2	3	4	5
1	Golden caesio dried Common slipmouth dried Pork tenderloin	Long jawed anchovy dried Common slipmouth dried Golden caesio dried	Golden caesio dried Goby fry, salted and fermented Tilapia	Beef liver Golden caesio dried Snack food	Milk sweetened condensed filled Snack foods Milk powdered
2	Golden caesio dried Common slipmouth dried Indian sardine dried	Common slipmouth dried Golden caesio dried Indian sardine dried	Golden caesio dried Common slipmouth dried Indian sardine dried	Canned chicken stew Beef liver Crab fat	Milk sweetened condensed filled Milk powdered Golden caesio dried
3	Canned chicken stew Indian sardine dried Golden caesio dried	Canned chicken stew Common slipmouth dried Indian sardine dried	Canned chicken stew Golden caesio dried Long jawed anchovy fillet	Canned chicken stew Small-scaled flying fish Golden caesio dried	Canned chicken stew Golden caesio dried Internal cow's organs
4	Golden caesio dried Round scad dried Indian sardine dried	Canned chicken stew Golden caesio dried Common slipmouth dried	Pigs legs Golden caesio dried Pork tenderloin	Golden caesio dried Common slipmouth dried Milk sweetened condensed filled	Internal cow's organs Pigs legs Hog, liver

Table 7b. Major sources of retinol by survey round and expenditure quintile for 4-6 year olds

	EXPENDITURE QUINTILE				
SURVEY ROUND	1	2	3	4	5
1	Golden caesio dried Pork tenderloin Common slipmouth dried	Long jawed anchovy dried Crab fat Golden caesio dried	Chicken liver Golden caesio dried Fresh water snail	Chicken liver Golden caesio dried Round scad dried	Carabao liver Chicken liver Round scad dried
2	Common slipmouth dried Golden caesio dried Round scad dried	Sardines in tomato sauce Golden caesio dried Pork tenderloin	Golden caesio dried Common slipmouth dried Indian sardine dried	Beef liver Canned chicken stew Golden caesio dried	Golden caesio dried Common slipmouth dried Crab fat
3	Canned chicken stew Indian sardine dried Long jawed anchovy, salted and fermented	Canned chicken stew Common slipmouth dried Golden caesio dried	Canned chicken stew Golden caesio dried Common slipmouth dried	Canned chicken stew Small scaled flying fish Common slipmouth dried	Canned chicken stew Internal cow's organs Golden caesio dried
4	Golden caesio dried Indian sardine dried Long jawed anchovy dried	Golden caesio dried Common slipmouth dried Indian sardine dried	Golden caesio dried Common slipmouth dried Pork tenderloin	Golden caesio dried Common slipmouth dried Pig's legs	Hog liver Golden caesio dried Pig's legs

Table 8. Median (1st and 3rd quartile) seasonal daily intakes of carotene and total vitamin A (New), old vitamin A values (Old), and non-starch polysaccharide (NSP) of Malawian preschool children (n=51).

	CAROTENE (ugRE)			TOTAL VITAMIN A (ugRE)		
	SP1[4]	SP2	SP3	SP1	SP2	SP3
New	437[1,2] (193, 1320)	768[1] (236, 1464)	423[2] (313, 724)	437[1,2] (219, 1320)	768[1] (253, 1482)	424[2] (313, 729)
Old				878[1] (428, 3224)	1323[1] (174, 2746)	592[2] (417, 991)
NSP				24[1,2] (18, 29)	20[1] (16, 24)	26[2] (20, 31)

[1,2,3], different numbers indicate significant differences comparing across seasons (Wilcoxons, P<0.05).
[4], S1, S2, S3, survey 1 (harvest; April), survey 2 (post-harvest; July), survey 3 (pre-harvest; November).
New, values obtained using revised food composition tables for carotene.
Old, values obtained using old food composition tables.

Table 9. Median (1st and 3rd quartile) percentage of total vitamin A (New) obtained from selected food groups by season of Ghanaian (n=75) and Malawian (n=51) preschool children

	FAT AND PURCHASED FOODS[5]	ROOTS	VEGETABLES	FRUITS	ANIMAL
GHANA-High[1]					
Survey 1	86[2] (69, 97)	1.5[2] (0.1, 24.0)	0.5[2] (0.3, 1.5)	0.1[2] (0, 3.6)	0.3[2] (0.1, 0.6)
Survey 2	90[2] (73, 96)	1.1[2] (0.5, 2.7)	1.2[3] (0.6, 3.0)	1.0[2] (0.1, 4.6)	0.5[3] (0.2, 2.6)
MALAWI					
Survey 1	0[2] (0, 0)	0.02[2] (0, 80)	71[2] (9, 92)	6[2] (1, 11)	0[2] (0, 0)
Survey 2	0[2] (0, 0)	66[3] (14, 86)	20[3] (11, 61)	1[2] (0, 9)	0[2] (0, 0)
Survey 3	0[2] (0, 0)	0.1[4] (0, 11)	21[3] (10, 38)	61[3] (37, 84)	0[2] (0, 0)

[1], new vitamin A values calculated using palm oil value for fresh red palm oil (High, 10,967 RE).
[2,3,4], significant differences comparing across seasons for this food group (Wilcoxons, P<0.05).
[5], The vitamin A content of the purchased foods was considered to come mainly from the palm oil content of these foods.

increase in vegetables as a percentage of total vitamin A in survey 1 and a significant increase of fruits in survey 3 it is the significant increase in roots as a percentage of total vitamin A in survey 2 ie. post harvest (reflecting sweet potato intake (pers. comm. E. Ferguson)) that appears to cause survey 2 to show significantly higher carotene and vitamin A intakes. Table 10 shows that total vitamin A expressed per meal does not change over seasons for meals prior to evening intakes. However, the total vitamin A content of meal 3 is significantly lower in survey 1 (harvest) compared to survey 3 (pre-harvest). The total vitamin A consumed in both these seasons is however not significantly different.

Table 11 shows the seasonal daily intakes of carotene (ugRE), total vitamin A (using revised food composition tables for carotene) and NSP (g) of Ghanaian preschool children. Large significant differences in carotene and vitamin A intakes can be seen across the two seasons using both values for palm oil ie. if fresh and if stale. No seasonal difference in NSP intake was observed. Surprisingly, intakes of carotene and total vitamin A fall significantly in the season commonly known as the season of plenty (season 2). Thus such designations of seasonal food shortage and food plenty do not apply to sources of vitamin A intakes. Vitamin A intakes from this data set had not been previously obtained using old food composition tables and thus the effect of revising the carotene analysis for foods consumed in the survey cannot be done. The reasons for the seasonal difference in Ghana is less obvious than in Malawi, but it is suspected that it is related to a lower consumption of palm oil in the 2nd survey as palm oil is the main source of vitamin A (eg. used in preparing stews, pers. comm. E. Ferguson). The food group 'fat' in Table 9 also contains purchased foods as the vitamin A contributed by these foods will be from palm oil (pers. comm. E. Ferguson). It can be seen that 86% and 90% of total vitamin A in Ghana comes from this food group for both the food shortage and food plenty season.

Table 10 shows for Ghana that there are large significant differences in total vitamin A intake expressed per meal over seasons for meals 2 (ie. lunch and afternoon) and 3 (evening and later in evening). The differences in total vitamin A intake over seasons expressed per meal between meals 2 and 3 and the magnitude of intakes in both meals for each season is very similar.

The vitamin A intakes for both Malawi and Ghana reached the safe level of recommended requirements in every season ie. 400 ugRE/d (FAO, 1988; see Table 6). Table 8 shows that the average NSP intake of the Malawian children is significantly higher when the vitamin A intake is lowest ie Rounds 1 and 3. In Round 3, the NSP intake of 26g/d is higher than the individual maximal level reference intake in the UK (24 g/d; Department of Health, 1992), and it is possible that such high levels of NSP may interfere with carotene absorption among Malawian children. Further analysis was undertaken to see what proportion (if any) within these groups of preschool children could be at risk. However, since the intakes of vitamin A are highly variable and 3 days of intake measurement may not be enough to reflect usual intakes per child per season the following breakdowns may not be acceptable as numbers in each group are likely to be small.

Table 12 shows a high proportion of children (approximately 2/5ths) in Malawi in each season had low intakes (<400ugRE vitamin A/d) although those at high risk ie. having vitamin A intakes below recommended requirements for all seasons was low for both Ghana and Malawi. The proportion with low intakes for one season only (and 2 out of 3 seasons in Malawi) was about a third for Malawian and a quarter for Ghana (2/5ths if stale

Table 10. Seasonal intakes of total vitamin A expressed per meal[1] of Ghanaian (n=75) and Malawian (n=51) preschool children

	MEAL 1	MEAL 2	MEAL 3
GHANA - HIGH[2]			
Survey 1	237[3] (18, 689)	1005[3] (476, 1743)	1040[3] (395, 1601)
Survey 2	218[3] (56, 416)	322[4] (115, 927)	342[4] (67, 860)
MALAWI			
Survey 1	104[3] (42, 764)	142[3] (59, 229)	35[3] (4, 112)
Survey 2	410[3] (48, 956)	160[3] (69, 312)	38[3,4] (12, 110)
Survey 3	189[3] (93, 387)	146[3] (78, 222)	47[4] (14, 73)

[1], meals=meal 1 (breakfast and morning intakes), meal 2 (lunch and afternoon intakes), meal 3 (evening meal and later in evening intakes).
[2], new vitamin A values calculated using palm oil value for fresh red palm oil (High, 10,967 RE).
[3,4], - different numbers indicate significant differences comparing meals across seasons (Wilcoxons, P<0.05).

Table 11. Median (1st and 3rd quartile) seasonal daily intakes of carotene, total vitamin A (New), and non-starch polysaccharide (NSP) of Ghanaian preschool children (n=75).

	CAROTENE		VITAMIN A	
	Survey 1[2]	Survey 2[2]	Survey 1	Survey 2
New -H[1]	2620 (1659, 3803)	1176[3] (427, 1978)	2644 (1686, 3811)	1176[3] (460, 1980)
New -L[1]	1560 (739, 2761)	526[3] (173, 1405)	1565 (748, 2804)	532[3] (209, 1409)
NSP			17.4 (13.6, 20.1)	17.2 (13.2, 20.2)

[1], New vitamin A values calculated using palm oil value for fresh red palm oil (New-H; 10,967 RE) and stale palm oil (New-L; 2617 RE).
[2], Survey 1=food shortage season (April-May), Survey 2=food plenty season (November-December).
[3], Significant differences comparing across seasons (Wilcoxons, P<0.05).

Table 12. Proportion of children in Malawi (n=51) and Ghana (n=75) potentially at risk of vitamin A deficiency

	MALAWI (%)			GHANA (%) High (Low)	
SURVEY ROUND	1	2	3	1	2
Proportion of children per season with low vitamin A intake	45	35	41	7 (11)	20 (14)
Proportion at high risk	8			1 (7)	
Proportion at low risk	25			75 (52)	
Proportion with low intake in one season	35			24 (41)	
Proportion with low intake in 2 out of 3 seasons	31				

palm oil was used by all subjects). Although the numbers of subjects within these risk groups were small these proportions may be cause for concern, especially in Malawi where the median intakes for 2 out of 3 seasons is just above the recommended safe level requirement.

4. Nepal data set

Table 13 shows that the new B-carotene content of the diet is much lower (almost 50%) than when old carotene composition values were used. In order to give a rough indication of the percent of carotene from different food groups for each month of the year a table was reproduced from data analyzed using the old food composition database. Table 14 shows that most of the B-carotene in the diet comes from fresh leaves. Less fresh leaves were eaten in the period July-August.

Table 13 shows that seasonal variation in B-carotene intake in the study area appears to be strong because the availability of fresh leaves changes during the year.

Energy intake appears to be stable throughout the year. The average yearly vitamin A intake for 1-6 year olds is extremely low ie. 104 ugRE (if 1:6 conversion is used). If the 1:4 conversion is used vitamin A intake is 151 ugRE/d. The number of subjects is small (n=17) but the weighed intake method covered 4-7 days specifically to attempt to cover a usual eating pattern. For children aged 7-15 years, men and women the vitamin A intakes per day (assuming the 1:4 conversion factor) were 265 ugRE, 399 ugRE and 467 ugRE respectively. As there is a statistically significant seasonal variation in vitamin A intake if the mean of all subjects is considered (see Table 11) it could be assumed that there will be a significant variation in intakes over the year for each age group. Table 6 shows that the intake of vitamin A for children aged 1-6 years, 7-15 years and for adult men fall below the basal requirements whereas intakes of adult women fall above the basal requirements but well below the safe level of intake.

C. DISCUSSION AND IMPLICATIONS FOR PROGRAMME DESIGN

This report has presented a review of the literature on seasonal differences in carotene intake. In doing so, it has necessarily considered some factors that could affect the accuracy of data presented in the studies reviewed. Issues discussed include:

a) Carotene content and methods of food analysis

b) Bioavailability of carotene in foods:
- absorption
- conversion to retinol

c) The methodology used to assess dietary intake: the review of this topic was presented in full in the intermediate report .

Also presented are some issues that affect the programmatic implications of seasonal

Table 13. B-carotene (ug) old and new values, retinol(ug) and energy (kcal) intakes of Nepali subjects by period of the year, by age and sex groups and by dwelling.

PERIOD OF YEAR	MEAN (SD) n=99	MARCH-MAY (SD) n=99	JUNE-AUGUST (SD) n=99	SEPT.-NOV. (SD) n=99	DEC.-FEB. (SD) n=99
B-carotene new (ug)	1363 (991)	2572[1] (3271)	767[2] (890)	957[2,3] (783)	1155[3] (1283)
B-carotene old (ug)	2559 (1465)	3098 (3392)	1517 (1399)	3580 (2318)	2043 (1685)
Retinol (ug)	19 (13)	12 (18)	19 (21)	25 (26)	19 (16)
Energy (kcal)	1845 (650)	1808 (645)	1803 (687)	1751 (707)	2019 (709)
AGE AND SEX GROUP	MEAN (SD) n=99	1-6 YRS (SD) n=17	7-15 YRS (SD) n=16	MEN 16+ YRS (SD) n=30	WOMEN 16+ YRS (SD) n=36
B-carotene new (ug)	1363 (991)	564 (460)	987 (641)	1505 (951)	1788 (1073)
B-carotene old (ug)	2559 (1465)	1056 (650)	1852 (917)	2855 (1308)	3337 (1420)
Retinol (ug)	19 (13)	10 (7)	18 (15)	23 (13)	20 (12)
Energy (kcal)	1845 (650)	677 (336)	1612 (322)	2326 (319)	2099 (222)
DWELLING	MEAN (SD) n=99	VILLAGE (SD) n=52	GOTH (SD) n=31	KAMI (SD) n=16	
B-carotene new (ug)	1363 (991)	1440 (1107)	1310 (904)	1213 (753)	
B-carotene old (ug)	2559 (1465)	2690 (1570)	2378 (1337)	2485 (1392)	
Retinol (ug)	19 (13)	17 (11)	27 (13)	8 (6)	
Energy (kcal)	1845 (650)	1848 (622)	1864 (663)	1801 (750)	

[1,2,3] Different numbers indicate significant differences comparing across seasons (Z test:P<0.05).

variations in carotene intake:

a) Depletion rates of liver stores of retinol, and hence the extent of protection that could be offered by increasing carotene consumption during the high season

b) Seasonality in carotene intakes in relation to seasonality in energy intakes, the child's growth spurt and the incidence of disease

c) The important contribution to carotene intake of specific foods during different seasons

In general, we have found conflicting results with regard to the relationship between dietary intake of carotene, serum retinol levels and clinical signs of ocular disease. This may be due to inaccuracies in the dietary studies or to other factors, some of which are discussed.

Our re-analysis of existing data sets, using new food composition values and different conversion factors, suggests that we may need to substantially reduce our estimates of intakes and bioavailability. In general, intakes were low, with many groups failing to reach requirement levels even during the high season. The important contribution of specific foods at different times of the year is highlighted.

The re-analysis also suggests that in areas of largely subsistence agriculture where the import and export of foods is limited, carotene and hence vitamin A intake generally follows the seasonal cropping pattern of the major sources of carotene and possibly also the prices of these foods. In areas of agricultural commercialization and crop exportation, households are able to generate income and intake of carotene may not necessarily follow the seasonal pattern of cropping; it could follow instead the prices of the major sources of carotenoids which may depend on factors outside the study area.

The programmatic implications of our findings are as follows:-

a) Higher intakes in one season could provide protection for a season of deficient intakes. The quantity of carotene needed during the high season to ensure adequate body stores to cover the low season could be determined, but factors such as reduced efficiency of absorption with high intakes of carotene need to be carefully considered.

b) When promoting the production and consumption of specific carotene-rich foods, programme managers should make all efforts to ensure that:

- the food is well accepted by the population

- the carotene content of the foods has been determined accurately by HPLC or OCC and that bioavailability has been tested in the target population.

- that agricultural production of the food is sufficient (or can be made sufficient) to cover increased demand; if this is not so, demand may increase prices and reduce accessibility by the poorest households.

c) We support the suggestion by Gopalan et al (1992) that countries should develop their own calenders indicating good, cheap sources of carotene and retinol by month and by region if necessary. Individual values for retinol equivalents for the major local sources of carotene should be developed to ensure accuracy when estimating the importance of particular foods.

d) The seasonal variability of factors affecting the bioavailability and requirements of carotene, such as the variation in NSP, protein and energy intakes, the prevalence of diarrhoeal disease and gastro-enteritis, should also be considered in programme development.

e) Carotene intake tends to depend on a few very rich sources eg certain green leafy vegetables, red palm oil, mangoes, yellow sweet potatoes. Methods to make rich seasonal sources available all the year round should be considered eg drying of fruits and vegetables, price subsidies. Careful consideration would need to be given to the effect of the food processing method on nutrient content in general, and not just on carotene content.

f) In each region of high VAD prevalence, attempts should be made to identify those communities or individuals who are at greatest risk, namely those who fail to achieve adequate intakes, even when carotene-rich foods are plentiful. Targeted, intensive programmes are required to meet the needs of these groups.

g) If cheap, culturally acceptable sources of retinol are available, these could be promoted. Where these are not currently available, planners should examine the possibility of small-scale animal-rearing projects.

h) If agricultural commercialization is underway in an area, its impact on micronutrient staus in general, and vitamin A status in particular, needs to be monitored. A suitable nutrition education programme might be need to offset a negative impact.

This study has identified a number of research areas that should be given priority. We do not intend to suggest that no work is underway in these areas; indeed much valuable ground has been covered. Rather we feel that efforts should be intensified so as to improve the design of national programmes and avoid costly errors.

These research areas are:

1. The development of better local food composition data, using accurate methods of analysis and considering also food losses during processing and cooking.

2. Bioavailability of carotene from different food sources, considering in particular the factors that can affect absorption, such as the individual's nutritional status and disease. This research may lead to recommendations for new conversion factors.

3. Better methods of food processing so as to minimize carotene losses.

4. Good, simple and validated methods for assessing vitamin A status and dietary intake.

5. Good studies of seasonal intakes of carotene and retinol. Our study has found too few of these.

6. The impact of agricultural commercialisation on micronutrient intakes. In the past, most studies of commercialisation of agriculture focused on its impact on energy availability.

7. Operational research on dietary strategies in general, to improve micronutrient intakes, are needed. More particularly, research is needed on how seasonal abundance can be harnessed to cover the carotene needs throughout the year.

8. While this study has focused on carotene, it is important not to forget retinol-rich food. If cheap, culturally acceptable sources are available, then their consumption should certainly be promoted. Research could examine also the impact of interventions promoting the consumption of at least small quantities of animal foods where appropriate.

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