

Full Length Research Paper

Vitamin A losses in a commercial food supply chain of fortified vegetable cooking oil and maize flour: A case from Malawi

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Vitamin A levels were analyzed in fortified vegetable cooking oil and maize flour through a commercial food supply chain, from the production line to selected retail outlets using standard procedures over different times of exposure to sunlight. Samples from the production line acted as controls. In all the cases, vitamin A levels decreased at various stages of the supply chain with the least retention in products sold by street vendors. Statistical analysis showed significant losses ($p < 0.05$) in vitamin A after the samples were exposed to sunlight. These results indicate that although food fortification is crucial in making micronutrients available to poor households, especially in developing countries like Malawi, there is need to sensitize retailers on proper handling and storage of these products to minimize losses in the supply chain.

Key words: Fortification, vitamin A, supply chain, sunlight, vegetable cooking oil, maize flour.

INTRODUCTION

Food fortification has recently been highlighted as one way of ensuring the supply of micronutrients to most of the population in the developing world (Heikens, 2007). For example, there have been mass fortification programmes in Zambia, Central America and Egypt (WHO, 2009) with the aim of decreasing micronutrient deficiencies among poor communities, especially children of 6-59 months and lactating women within 8 weeks of child birth (GoM, 2009). A national micronutrient survey conducted in Malawi in 2001 found that 60% of children

under the age of five, 57% of women of child bearing age, and 38% of school children were suffering from sub-clinical vitamin A deficiency (VAD) (GoM, 2009). Such high levels of micronutrient malnutrition have been linked to ailments which include low immunity, impaired physical, mental and psychomotor development and severe cases, night blindness. Such effects may affect child's mental development and in the long term national economic development may suffer. Vitamin A deficiency has been reported to cause childhood blindness to

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estimated 140 million children worldwide (Combs, 2012). Severe vitamin A deficiency has also been reported in several sub-Saharan countries including Nigeria, Egypt, South Africa, Kenya, Namibia and Tanzania (Klemm et al., 2010). In South Africa, a country with a relatively good economic standing in Africa, it was recently found that 49% of preschool aged children and up to 68% among women of reproductive age had VAD (Mostert et al., 2005). These data are worrisome and certainly suggest an urgent need for interventions.

Despite the severe consequences that result from vitamin A deficiency, the good news is that a diverse diet, which includes foods of animal origin that are rich in preformed vitamin A (esters of retinol), might be sufficient to satisfy the daily requirements of vitamin A. However, in most developing countries, diets are monotonous (Ruel, 2001) and mainly based on cereals and legumes that are poor sources of vitamin A (West et al., 2002; WHO, 1998). Vitamin A is virtually absent in whole-grain cereals and flours. Because vitamin A deficiency results mainly from chronic dietary insufficiency, food fortification has been identified as an effective approach to abate the problem (Klemm et al., 2010). For example, it is possible to fortify flour from cereal grains using a powdered form of vitamin A, retinyl palmitate which has been found to be more stable than retinyl acetate (Combs, 2012). The fortification of vitamin A, which is fat soluble, in cooking oil is even much simpler and cheaper and can be done either with retinyl acetate or retinyl palmitate in oil base (Johnson, 1997).

In a drive to promote the reduction in micronutrient deficiency, the government of Malawi has been advocating for micronutrient supplementation of foods. In addition to iron and iodine, one of the target micronutrient for this exercise is vitamin A and the food vehicles chosen are sugar, vegetable cooking oil and maize flour (Yeudall et al., 2005). Fortifying a widely consumed food product or additive makes it easy to deliver low doses of vitamin A daily to a large number of people (Dary and Mora, 2002). This was the rationale behind the choice of these foods that are consumed by the majority of Malawians most of who live on less than 1 US\$ per day. Actually, the current Human Development Index for Malawi is 0.400 and not only ranks Malawi at 141 out of 187 countries with comparable data but also puts it below the average for sub-Saharan Africa which is at 0.463 (UNDP, 2012).

Regardless of whether the vitamin A occurs naturally or has been added to a food product through fortification or other means, the potential exists for losses by chemical or physical means. These losses may also occur due to exposure to light and heat exposure resulting into oxidation (Butt et al., 2007). Vitamin losses are to some extent inevitable in the manufacturing, distribution, storage and preparation of processed foods (SUSTAIN, 1999). Retention of vitamin A in fortified foods is important for determination of the efficacy of the

fortification programs. It is therefore important to understand the degree of loss in the supply chain so that proper strategies can be put in place to ensure that the consumer is getting the intended dosage of the micronutrient (Butt et al., 2007). The Malawi Bureau of Standards (MBS) recommends a vitamin A content range of 30 to 60 mg/L for vegetable cooking oil and 10 to 40 mg/l for maize flour (SUSTAIN, 1999).

In Malawi, however, vitamin A losses in the food supply chain have not been evaluated. This study therefore assessed the extent of vitamin A losses in a supply chain of fortified food vehicles which comprised two brands of vegetable cooking oil and maize flour.

MATERIALS AND METHODS

The study was done in Blantyre City, Malawi, targeting one major flour producing company, and two major oil manufacturing factories in Malawi's commercial capital. One of the oil factories produces vitamin A fortified soybean cooking oil while the other produces vitamin A fortified sunflower cooking oil.

Sample collection from production line

Triplicate samples (1 L each) of freshly produced fortified vegetable cooking oil (sunflower and soybean) were collected from the two sampling points. Triplicate (1 kg) samples of fortified maize flour were also collected from the production line of the flour company. The fortified cooking oil and fortified flour bought from the manufacturing companies acted as a control. Fresh samples from production line were analyzed immediately after sampling and the remaining portions were analyzed after exposure to sunlight at intervals of seven, fourteen and thirty five days.

Sample collection from retail markets

Sampling from the retail markets was done by gathering information on the cooking oil bottles (batch coding and manufacturing date) to determine the most recent batch for use in the study. This was done because it was difficult to trace the same batches that had been sampled from the production line to the targeted retail markets. The most recent batches of soybean cooking oil sampled from Usave supermarket were the ones that had been stored in the shop for fifteen days from the manufacturing date. Ndirande market soybean cooking oil samples were analyzed after being retained by the retailer for six days while Zingwangwa market soybean cooking oil samples were analyzed after being retained by the retailer for seven days. Recent batches for sunflower oil had been in the supermarket for thirteen days on the day of sampling and the sunflower oil from Ndirande and zingwangwa market were three and five days old on the day of sampling. Flour samples collected from Usave supermarket had been stored for ten days from the manufacturing date while Ndirande and Zingwangwa samples were five and six days old respectively on sampling day. Triplicate 1 L samples of the same brands of fortified vegetable cooking oil were bought from a supermarket (USave) and street vendors in two open markets (Ndirande and Zingwangwa) in Blantyre City. Samples of cooking oil and maize flour from the retail markets were analyzed immediately after collection. The percent loss in vitamin A was calculated using the following formula:

$$\text{Loss (\%)} = \frac{[(\text{initial vitamin A content} - \text{new vitamin A content}) / \text{initial vitamin A content}] \times 100}{1}$$

Vitamin A analysis

Vitamin A analysis in oil

Analytical procedures used in vitamin A analysis of the oil samples are those from the manual for internal monitoring of oil fortified with vitamin A (East, Central and Southern African Health Community, 2007). Approximately two grams of oil was weighed into a twenty 5 ml 25 ml volumetric amber flask and mass was recorded to four decimal places. Dichloromethane was added to the flask to dissolve the oil and mixed thoroughly. The same process was repeated using unfortified (blank) oil. Absorbance reading of samples and unfortified control was read on a spectrophotometer at 325 nm. Retinyl palmitate concentration of the oil sample was estimated using the following equation:

$$\text{Retinyl palmitate (mg/kg)} = \frac{\text{Abs corrected} \times \text{Vf} \times \text{CF spec}}{a \times w}$$

Where Abs corrected = Abs sample – Abs unfortified oil; Vf = final volume; CF=correction factor of the spectrophotometer, ideally; a= retinyl palmitate absorption coefficient in dichloromethane (mg-1 cm-1 L) 0.094; w= weight of sample.

Vitamin A analysis in flour

Vitamin A in flour was determined using spectrophotometric method (AOAC, 2002). About 0.05-1 g of flour and thick porridge samples were weighed using analytical scale (Model: ADAM PW 124) into 50 ml conical centrifuge tube. Six milliliters of dichloromethane was added to samples. The mixture was vortex for 2 min, and then 1.0 ml of methanol was added to the mixture and vortexed for 2 min. Ten milliliters of distilled water was added to the mixture, the vortex for 1 min. The mixtures were centrifuged for 2 min to separate the two phases. The dichloromethane phase went to the bottom. Using the Pasteur pipette, the flour pellet that were formed between the two liquid phase was set aside, and then the organic phase was transferred in to 10 ml measuring cylinder. The mixture was left to stand and the remaining water was removed with a Pasteur pipette, then the volume of the extract was recorded. The volume of extract was used to calculate the concentration. The extract was used for the determination of vitamin by directly recording the absorbance at 325 nm.

Preparation of standard vitamin A solution

One hundred milliliters amber was tare on an analytical balance. Using the pipette, 75.6 mg of standard retinyl palmitate (USP) was transferred into volumetric flask. Then dichloromethane was added to the flask to dissolve the vitamin A and make up the volume. Taking into account the actual concentration of the stock solution, appropriate aliquots was pipetted into a set of 50 ml amber volumetric flasks to give a set of standard solutions. A standard plot was prepared by reading the absorbance of the standard solutions of vitamin A. To 50 ml of volumetric flask, 0.1, 0.2, 0.3, 0.4 and 0.5 ml of standard solution was pipetted, then made up to the volume. The absorbance of these solutions was read at 325 nm and a standard plot was made. The absorbance of sample extract was measured and compared against the standard plot to determine the concentration. The following formula was used to calculate vitamin A concentration in samples. The concentration of vitamin A in extract of samples, treated in a similar manner to the standard solution was calculated using slope and constant of the standard plot.

$$\text{Absorbance} = \text{Slope} \times \text{concentration} + \text{constant}$$

Therefore

Concentration of vitamin A = (Absorbance – Constant) / slope of plot

Concentration of vitamin A (mg retinol/Kg Flour) would therefore be according the following:

$$\frac{\text{Conc. Of vit.A in extract (M)} \times \text{vol (ml) of extract solution} \times 5.249 \times 10^5}{\text{Mass of Flour weighed (g)}}$$

Data analysis

The mean, standard deviation and 95% confidence intervals (CI) of the mean were calculated using SPSS version 20. Single factor analysis of variance (ANOVA) and Turkey Honest significant difference (HSD) post hoc tests were also done using SPSS.

RESULTS AND DISCUSSION

The Malawi Bureau of Standards recommends 30-60 mg/l (Malawi Standard 51, 1988), in vegetable cooking oil and 10-40 mg/l in maize flour. This study results generally indicated varied vitamin A losses in all samples along the supply chain and during exposure to sunlight but drastic changes were observed in maize flour which lost up to 61% after 35 days of exposure to sunlight and an average of 55% in samples from street markets (Table 1). Actually, after two weeks of exposure to sunlight, maize flour had already lost most of the vitamin A to levels below the Malawi Bureau of Standards minimum value of 10 mg/l. The vitamin A loss in maize flour could be attributed to storage conditions (left in open basins at the market) of the flour which led to direct exposure to light.

One way of analysis of variance (ANOVA) showed that there was significant loss of vitamin A levels in fortified sunflower oil after 35 days of sunlight exposure as compared to fortified soybean oil; 40% versus 27% (p < 0.05) respectively. The results obtained in this study for vitamin A loss in fortified soybean oil are in agreement with the finding of Puysuwan et al. (2007) who noted that fortified soybeans oil in losed PET bottles exposed to sunlight for 4 weeks at room temperature reduced thr initial vitamin A concentration by $27.1 \pm 12.1\%$ without accounting for the oxygen exposure upon opening. The vitamin A losses in oils and maize flour from samples from street vendors (Table 2) could be attributed to prolonged exposure to sunlight and also the nature of the packaging material used (sachets for oils and basins for flour) by the vendors (Chakravarty,2000). This is so because packaging is also a contributing factor to the losses in Vitamin A (Oluwalana et al., 2015).

Loss of vitamin A in vegetable cooking oils was lower than in maze flour and this could be attributed to the fact that oil stabilizes retinol and delays oxidation of the vitamin (Dutra- de – Oliveira, 1994, Pignitter et al., 2012). Though the samples used were produced by large

Table 1. Vitamin A levels (mg/l) in the various samples analyzed from production line.

Sample source and treatment	(Soybean oil)	(sunflower oil)	(maize flour)
Production Line – Fresh	41.37±0.09 ^a	36.76±0.13 ^a	21.53±0.93 ^a
Production Line – 7 day sunlight exposure	33.89±0.64 ^b	27.35±0.56 ^b	10.92±0.46 ^b
Production Line – 14 day sunlight exposure	31.98±0.52 ^c	24.06±0.29 ^c	9.22±0.35 ^c
Production Line – 35 day sunlight exposure	30.11±0.04 ^d	22.83±1.69 ^c	8.49±0.06 ^c

Values are mean ± standard deviation of triplicate samples. Values within the same column with the same superscript are not significantly different ($p < 0.05$).

Table 2. Vitamin A levels (mg/l) in the various samples analyzed from retail markets.

Sample source and treatment	(Soybean oil)	(sunflower oil)	(maize flour)
Supermarket	37.51±0.86	36.12±0.17	17.68±0.53
Ndirande Market	31.91±0.18	30.15±0.44	9.25±0.91
Zingwangwa Market	31.57±0.80	29.78±0.89	10.04±0.34

Values are mean ± standard deviation of triplicate samples.

manufacturing industries in Malawi, the authors acknowledge the limitation that the sampling points were only in one location (Blantyre). Other retailers who also serve a large portion of the population were left out, making the findings suggestive of the likely trend to be observed nationwide rather than being conclusive. The study did not measure the peroxide values of the oils which are also influenced by exposure to sunlight. For this reason, it is recommended that further studies should include a measure of the peroxide values of the oils which would give an indication of the quality (Chabiri et al., 2009) and storage stability of the product.

Conclusions

This study shows loss of vitamin A in the commercial food supply chain of vegetable cooking oil and maize flour upon exposure to sunlight. Handling of vitamin A fortified foods should therefore be away from sunlight. The study also revealed higher vitamin A loss in maize flour than vegetable cooking oil when exposed to sunlight for the same duration. Sunflower cooking oil also exhibited higher vitamin A losses than soybeans oil. It is therefore recommended that more effort in future interventions of abating vitamin A deficiency should focus on soybean cooking oil as a vehicle. Retailers should also be sensitized on the importance of proper handling and storage of fortified cooking oil and maize flour to avoid loss of vitamin A.

Conflict of Interests

The authors have not declared any conflict of interests.

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