Skimmed milk as a determinant of vitamin A deficiency

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Objective: To compare the levels of vitamin A in ultra-high temperature treated (UHT) whole milk (3.5% fat) and UHT skimmed milk (0.5% fat) using UV-visible light spectrophotometry and to compare the contribution of whole milk and skimmed milk to the recommended dietary allowance (RDA) for vitamin A.

Design: Paired samples of liquid whole milk and liquid skimmed milk were used. Sampling and analysis were performed by different individuals to achieve a randomised blind design.

Outcome measures: Thirty paired samples (n = 30) of whole milk and skimmed milk were evaluated for vitamin A content using UV-visible light spectrophotometry at 328 nm.

Results: Absolute concentration of vitamin A was reduced from 208.830 ± 0.083 μg/L in whole milk to 35.855 ± 0.046 μg/L in skimmed milk. The 85.7% reduction in butterfat content from 3.5% in whole milk to 0.5% in skimmed milk was accompanied by an 82.824 ± 3.51% (mean ± SD) reduction in retinol content.

Conclusion: The contribution of milk to the RDA for vitamin A was reduced from the standard 7.6% for whole milk to 1.30% for skimmed milk with 0.5% fat. The results emphasise the need for fortification of skimmed milk with vitamin A in order to augment the prevention of vitamin A deficiency diseases in developing countries.

Keywords: recommended dietary allowance, skimmed milk, vitamin A, whole milk
Optical density of vitamin A in skimmed milk

1.345 × 10⁻⁶ L/cm/mol. Filtered distilled water was used as a blank. Vitamin A is fat-soluble and hence certainly absent in pure water. All experiments were carried out in duplicate and the results expressed as mean ± standard deviation (SD). Optical density was converted to vitamin A concentration as follows:

\[
\text{Concentration of vitamin A} = \left( \frac{\text{Optical density of sample}}{\text{Optical density of standard}} \right) \times \text{Concentration of vitamin A in standard.}
\]

Modern spectrophotometers are equipped with a photomultiplier that ensures adequate sensitivity of the instrument in the entire UV-visible region of the electromagnetic spectrum. The detection limit of the instrument in the present study was 0.001 absorbance units, equivalent to a vitamin A concentration of 0.213 μg/L.

The measurements of vitamin A levels in milk were carried out in the Analytical Chemistry Laboratory of the Department of Preclinical Veterinary Studies, Faculty of Veterinary Science, University of Zimbabwe. Two suitably qualified and trained technicians performed the analysis. The coefficient of variation of the extractions and spectrophotometry analyses, as computed from the formula, standard deviation/mean, was 0.276 for skimmed milk compared with 0.084 for whole milk. Thus sensitivity of UV-visible light spectrophotometry decreased with decreasing vitamin A concentration in skimmed milk compared with whole milk. The level of significance was set at 95% confidence limits (\( p < 0.05 \)).

**Results**

In spectrophotometry the concentration of a substance is directly proportional to its optical density, or absorbance. It was thus possible to quantify the loss of vitamin A from whole milk upon skimming by comparing the optical density of the nutrient in whole milk and skimmed milk. In all cases, consistently lower levels were recorded for skimmed milk compared with full cream milk. Figure 1 shows the optical density of vitamin A in skimmed whole milk and the standard, depicting the reduction in concentration of vitamin A in skimmed milk relative to whole milk.

The average loss of vitamin A from skimmed milk expressed as a percentage of whole milk was 82.824 ± 3.51% as computed from the formula:

\[
\text{Percentage of whole milk} = \left( \frac{\text{Concentration of vitamin A in skimmed milk}}{\text{Concentration of vitamin A in whole milk}} \right) \times 100
\]

The RDA for vitamin A ranges from 400 μg/day in infants below 6 months old, through 700 μg/day for adult females, to 900 μg/day for adult males. Whole milk is a good source of vitamin A.

**Discussion**

The present study elucidated a significant reduction of vitamin A in skimmed milk in comparison with whole milk. Milk skimming involves extraction of butterfat from whole milk for the manufacture of butter as well as various kinds of cream. Inevitably, fat-soluble vitamins partitioned in the fat portion of milk were also removed during the skimming process. Therefore, apart from a low fat content, skimmed milk also happens to be low in fat-soluble vitamins. In developing parts of the world, deficiency of vitamin A in skimmed milk has received very little attention with the effect that the milk is marketed without any attempt to replace lost vitamins. In the present investigation, the contribution of skimmed milk with 0.5% fat to the RDA for vitamin A was a paltry 1.30%, compared with the standard 7.6% for whole milk with 3.5% fat. The results emphasise the need for fortification of skimmed milk with vitamin A in order to augment the prevention of vitamin A deficiency diseases in Zimbabwe as well as other countries where fortification is not mandatory.

Table 1: Concentration of vitamin A in skimmed milk compared with whole milk (Mean ± SD)

| Sample         | Concentration of vitamin A (μg/L) |
|----------------|-----------------------------------|
| Skimmed milk   | 35.855 ± 0.046                    |
| Whole milk     | 208.830 ± 0.083                   |

Reduction in butterfat content from 3.5% to 0.5% caused loss of milk fat equivalent to 85.714%. Hence the correlation between milk fat content and vitamin A content was 97.28%.

Table 1 shows the actual concentrations of vitamin A in skimmed milk and whole milk as calculated from the optical density of skimmed milk, whole milk and the vitamin A standard.
The physiological functions of vitamin A and its derivatives have been extensively reviewed and are summarised as follows. Retinol is critical in vision. Retinoic acid functions in maintenance of the integrity and innate immunity in epithelia (cornea, respiratory tract, digestive tract and reproductive tract). It is also involved in specific immunity by influencing differentiation of T cells. Other functions of retinoic acid include cell growth and development. With reduction in vitamin A content in skimmed milk, the contribution of milk to the RDA for vitamin A was reduced by well over 80%. Consumption of skimmed milk in poorly resourced settings therefore should be seen as a determinant of poor vitamin A status. In a worldwide survey by the World Health Organisation,13 190 million children under the age of five years and 19.1 million pregnant women had biochemical vitamin A deficiency, i.e. low serum retinol concentrations. Of this, 2.55 million children and 3 million expectant mothers suffered from night blindness, an indicator of clinical vitamin A deficiency. Other manifestations of vitamin A deficiency include xerophthalmia, permanent blindness, hyperkeratosis, anaemia and nutritionally acquired immune deficiency.14 It is clear that any factor that contributes to a reduction in the dietary intake of vitamin A in vulnerable groups is highly undesirable, including plain skimmed milk. Although controlled studies on consumption patterns of skimmed milk in developing countries are lacking, intake of skimmed milk is likely to be higher in women of child-bearing age than other population groups, fuelled by the desire to ‘shed’ weight. As a result, offspring from vitamin A-deficient mothers may be at risk of hypovitaminosis A. Another factor that may increase consumer preference for skimmed milk, particularly among the health-conscious population groups, is the low cholesterol content of the milk.

As shown in Figure 1 vitamin A exists in milk chiefly as retinol. Results from the current investigation affirm that sufficient levels of vitamin A are normally present in whole milk from intake of fresh forages or silages.15 As in previous studies, variations occurred in concentrations of vitamin A from sample to sample. Absolute concentrations of vitamin A in milk vary according to season, with increased levels in the summer months.16 Variations in concentrations of vitamin A in milk also occur with diet17 and with the stage of lactation.18 In spite of the limitations to the study posed by the diverse sources of variation, the present results fell within the previously reported range of vitamin A concentration in whole milk. The average concentration was marginally lower than reported for whole milk prior to processing, pointing to a possible depletive effect of ultra-high temperature treatment. The principal limitation of UV-visible light spectrophotometry is that it does not distinguish between two substances that absorb light at identical wavelengths. For this reason, an empirically determined wavelength of 328 nm was used in the spectrophotometric measurements, the validity of which was confirmed from the standard solution of vitamin A. In conclusion, reduction in vitamin A content in skimmed milk relative to whole milk was a consistent finding. This study represents the first scientific report on vitamin A concentrations in skimmed milk. Further studies are clearly essential to fully explore the impact of the depletion, and its consequences on nutrient status, particularly of vitamin A and other fat-soluble vitamins at various levels of skimming.

Conflict of interest – There is no conflict of interest to declare.

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