Fortification of milk by supplementing dairy cows- A One Health Approach to Maternal and Child Under Nutrition

Executive Summary

In the World Bank Investment Framework for Nutrition year of action 2021, the aim of this discussion paper is to explore some of the issues raised by current thinking on Maternal and Child under nutrition.[1]

The current approach to stunting, wasting and anaemia using supplements runs in to the problems of long term funding and compliance. The use of artificial supplements, in whatever form, while addressing the specific problem also promotes highly processed food to semi literate populations. By promoting through mass media and health professionals that supplements are good, are we undermining the fresh food message. Are we by default promoting processed foods and poorer more expensive diets?

We would like to propose a One Health approach to supplement dairy cows with Cobalt,Iodine, Zinc and Selenium by ruminal boluses. If successful, farmers would be prepared to pay for the boluses for the increased fertility and milk production. The cows would ferment the Cobalt to Vitamin B12 and high levels of Vit B12, Iodine, Zinc and Selenium in the milk would provide the supplementation. The intake of the dairy products would also provide high quality protein and additional energy. The improved dairy production would reduce the carbon footprint per litre of milk. If a diagnostic support and market system can be established then the supplementation would be self funding and sustainable.

Introduction

2013 - Under Nutrition is responsible for 45% childhood mortality and a major cause of adult chronic diseases.
The first two and a half years of life, 1000 days are the most important for both child and future adult health.

Literature reviews show high prevalence of deficits in vitamins B12 and D, iodine, zinc, folate and iron in several LMIC settings, with 50% Maternal Anaemia the norm.

Overall, there are scant data on biochemical markers of micronutrient deficiency, particularly in Africa.(in humans).

There is also what has been called the double and triple burden of anaemia, stunting and obesity, as incomes rise and an increase in western style processed food diets.

In a literature search for cattle trace element markers in Nigeria, the only known paper was 1965 and is currently inaccessible.

Problem statement

There have been many successful interventions to address deficiencies using supplementation. Where this is by regulation of products such as iodisation of salt to address iodine deficiency these are sustainable and can be successful in the long term.

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[1] Ref's from-The Lancet Series on Maternal and Child Undernutrition Progress- https://spark.adobe.com/page/WfzqOry1ynbub/

However the approach to stunting/wasting and anaemia using supplements such as Balanced energy protein supplementation or UNIMMAP, or iron or folate acid tablets run in to the problems of long term funding and compliance.
The use of Small quantity Lipid Nutrient Supplements (SQ-LNS) are very effective in trials and in funded programs.

The Lancet recommendations of the *eleven sumarai* are an excellent nutritionalists approach to the problems. While not disagreeing in anyway with those recommendations, we would like to start a discussion on a one health approach to supplementation that also then addresses food insecurity and by increasing food production, alleviates poverty.

While the use of artificial supplements, in whatever form, while addressing the specific problem also promotes highly processed food to semi literate populations. By promoting through mass media and health professionals that supplements are good, are we undermining the fresh food message? Are we by default promoting processed foods, poorer more expensive diets?
Are we promoting future obesity?

According to WHO 2018, Animal Source Foods (ASF) are the best quality nutrient rich food for 6-23 months.
59% of children are not fed much needed nutrients in LMIC: UNICEF

Part of USAID's program principles is: *Develop local capacity and systems to establish durable means to meet local needs.*
We would like to shift the discussion from using supplements to ensuring that diets are adequate.

One Health Approach

We would like to suggest a one health approach that looks at the bigger picture. While much more complex and requiring local culturally appropriate initiatives, more monitoring and much more research, it could yield longer term benefits: Not just in *Reduction in Maternal and Child Undernutrition* but improvements in local agriculture, in the local economy and in food security. Any implementation would need to be contextualised, with data collection alongside the implementation.

We would like to propose a pilot project; The fortification of milk by supplementing dairy cows- A One Health Approach to Maternal and Child Under Nutrition

Ruminant

The four traditional trace elements (TE) in ruminant nutrition are copper, cobalt, selenium and iodine, although there are a number of other trace elements which are considered to be of minor significance.
In the UK an estimate of 10,000 cattle samples are routinely analysed for nutritional status per year.(DHHPS, University of Edinburgh). In two countries where we have undertaken a literature review and discussed with experts in the field, Sri Lanka and Nigeria the only samples that have been taken are by our team.

There are a number of different mechanisms whereby TE deficiencies can occur. In primary deficiencies (such as selenium and cobalt deficiency), low levels of TE are present in the soil, which results in low pasture levels, and then low levels of the particular TE in the animal. However in secondary or conditioned TE deficiencies, there are a number of dietary antagonists present that interfere with the uptake and absorption of the mineral from the diet. In copper deficiency in adult ruminants, the presence of antagonists such as molybdenum, iron and sulphur in the diet results in the development of insoluble copper complexes in the rumen, which reduces copper absorption. Some animal feedstuffs such as clover and brassicas may contain high levels of goitrogens, which interfere either with iodine absorption or thyroid hormone production, resulting in the development of secondary iodine deficiency.

This makes the identification, diagnosis and correction of TE deficiencies difficult in ruminants. Analysis of soil and feedstuffs for levels of TE can be useful for primary deficiency, and indeed geographical maps are available in the UK for areas that are prone to selenium and cobalt deficiency based on soil type. Similar soil maps are being developed for many areas.
They can also be helpful to identify the presence of antagonists such as molybdenum which might give an indication as to the likelihood of copper deficiency. However animal testing is usually required for definitive diagnosis, either assessing concentrations of TE in the bloodstream or tissues, or the activity of various enzymes or hormones that are dependent on TE concentrates, and are therefore used as an assessment of TE function.

It is known that supplementation of dairy cattle with cobalt increases the levels of vitamin B12 in the milk to human dietary requirements. Dietary cobalt is utilised by microbes in the rumen to synthesise vitamin B12. The rumen microflora converts the cobalt to vitamin B12, which is then absorbed by the cow and excreted in the milk. Excess dietary iodine is secreted in the milk. Animal products are the principal dietary sources of cobalt containing vitamin B12 for humans.

Low cobalt levels (and the associated low vitamin B12 levels) in cattle are associated with poor production and weight gain, reduced appetite and reduced fertility. Dietary levels of 0.04- 0.06 mg/kg DMI (Suttle) are usually enough to ensure that vitamin B12 in animals is maintained at a normal level. (above 0.3 mg/L, Marston, 1970). Recent work suggests that production parameters can be improved by higher levels of up to 0.25 mg/kg DMI (Lopez-Guisa and Satter, Zelenak et al. 1992). It is suggested at these higher levels that both rumen and immunological function are improved independent of adequate vitamin B12 levels.
Cobalt levels in crops and forages can be very geographically-specific depending on the underlying geology of the soil and interactions in the soil. Our recent work shows that most of the fodders tested from northern Sri Lanka are deficient in cobalt
Improving milk production and cattle growth rates will improve farmer income and nutrition of the local population.

For example Nigeria:
FAO estimate 23 million cattle of which perhaps 10% provide milk for human consumption.
FAO estimate 500,000 tonnes milk are produced for consumption.(Which is equivalent to 500m litres or 200-250 litres per year per cow) Other estimates (Sahel Consulting) give 20 million cattle of which 2.3m are dairy cows. National Bureau of Statistics estimated the population of Cattle to be 19.2m Cattle
The National Livestock Development Plan 2018-2027 puts a census as an urgent priority and opens its Executive summary with: “The livestock industry in Nigeria has been bedeviled with slow growth and poor productivity”
..milk production is extremely poor with about 1 litre/cow/day compared to Brazil and Saudi Arabia of 30-40 litre/cow/day.

The liveweight slaughter of beef cattle at a Nigerian abattoir was 100-200kg (cf to UK values of 660-800kg) (Olorunshola, Ilorin).

Average Calving Intervals (the time between one calving and the next) in a SEBI Ethiopian study was 23-27 months. The UK target is 12 months but even improving to a poor (by UK standards)15 months would increase calf production by a third.

While the reasons for poor productivity is multi factorial; poor energy intakes (forage availability), protein intake, water availability (ruminants ferment their fodder and water access improves the fermentation) as well as disease, but in our view the mineral status of ruminants has been neglected.

Assessing and addressing supplementation of cattle will increase production, fertility and immune response in cattle with benefit to the human population.

Human Population

It is known that supplementation of dairy cattle with cobalt increases the levels of Vitamin B12 in the milk to human dietary requirements, as dietary cobalt is utilised by microbes in the rumen to synthesise Vitamin B12. Excess dietary iodine and selenium is also secreted in the milk. Copper levels in milk however do not vary.

Iodine

Iodine deficiency and goitre are a known problem in the human population, despite the traditional public health approach of the mandatory iodisation of salt (https://fortificationdata.org/country-fortification-dashboard/).

For Example: Sri Lanka

Fernando et al. (Ceylon Med J. 2015) report the island-wide adjusted prevalence of goitre to be 6.8% (95% CI = 6.0-7.6), implying considerable iodine deficiency. Another study which found Sri Lankan iodine deficiency in pregnancy identified cow's milk as the main source of iodine in the diet, with the average consumption around 200ml/day.(https://www.ncbi.nlm.nih.gov/pubmed/26693434).

Dairy milk is usually seen as a source high in iodine. The recommended daily intake is 150ug/day for adults, rising to 250ug/day for pregnant or lactating women.(https://www.ncbi.nlm.nih.gov/books/NBK254244/). In our recent study, bovine milk had a much lower level of iodine at 90 µg/litre than the reported UK levels of 144 ug/ litre for organic and 249 µg/ litre for conventional milk. The McCance & Widdowson's database report a higher level of 310 ug/kg (2009) for UK whole, pasteurized milk. (1kg=1L)

Dairy milk in northern Sri Lanka does not currently provide the dietary iodine expected in milk. In dairy cattle about 80 to 90 percent of dietary iodine is absorbed and most of the iodine not taken up by the thyroid gland is excreted in urine and milk (Miller et al., 1988). So, any supplementation would be expected to raise the levels in milk; the iodine content of dairy milk has been shown to increase as dietary iodine increases making the iodine content of milk a reasonable indicator of iodine status (Berg et al., 1988).

Cobalt

Milk and dairy products provide a significant role in providing vitamin B12 in human diet. However there are scant data on biochemical markers of micronutrient deficiency.

For example: Only two published surveys on vitamin B12 levels in Sri Lanka have been identified. These were in South Sri Lanka and did not target low meat-eating populations (Micronutrient Status in Sri Lanka: A Review by Hansani Madushika Abeywickrama).

There is evidence that sub-clinical vitamin B12 deficiency is common in south India where vegetarian diets are common.(Christian et al 2015). Figures for low meat-eating populations of Sri Lanka, who would then rely on milk (and eggs) for their vitamin B12 intake, are not readily available. The population of Sri Lanka is 21 million (2017) of which 70% are Bhuddist and 12% Hindu. Traditionally Buddhists and Hindus would be vegetarian. The estimate is about a fifth of the Buddhist, and a tenth of Hindu population will probably consume red meat. So we might estimate that between half and two thirds of the Sri Lankan population are vegetarian (Personal Communication C.Williams, Ygro).

National micronutrient study in pregnant women in 2017, NNMSPM2017 reports pregnant women on average consumed milk in 5.6 days of the previous week of the survey compared to 2.1 days for eggs and 1.1 days for meat and 1.5-3.2 for fish products. Milk is therefore an important nutritional source.

In our study, the calculated[2] vitamin B12 levels in bovine milk varied from 2.3-34 µg/litre (an average of 10 µg/litre) with three quarters of cows being below the average 10 µg/litre. As the Recommended Nutrient Intake of vitamin B12 for humans is 2-2.4 µg/day, consuming the average 200 ml of milk or milk product could provide adequate vitamin B12 supplementation.

Zinc

Zinc supplementation for human health and has been shown to reduce the incidence of diarrhoea by 11%. Zinc is excreted in the milk and reflects the zinc status of the cow.

So supplementation of dairy cow feeds with zinc increases the zinc levels to the cow.

Selenium

Selenium deficiency while common in ruminants, in humans is associated with the depletion of the antioxidant selenoenzymes, resulting in impaired antioxidant activity and immuno suppression.

Selenium levels in leafy greens can be boosted using selenium fertilisers, or levels in milk by supplementing cattle or their fodder. Selenium is excreted in the milk and levels reflect the cows selenium status. Selenium enriched milk is available to purchase in the UK: NEMI milk.

Discussion

The levels of minerals and Vit B12 in milk in LMIC is probably much more variable than the traditional values given in developed countries. (eg CoFID). The breeds of cattle, fodders, water supplementation are all much more variable than the european monocultures. There will also be significantly less mixing in the processing chain, which averages out values.

Our proposition is to use a one health approach and fortify milk with iodine, Vit B12 (Cobalt), Selenium and Zinc so that 250ml of milk or milk product provides the maternal Recommended Nutrient Intake.

The advantage of this approach is that it is completely sustainable. Farmers will pay for the supplementation of their animals for the ruminant health benefits and improved production and fertility. (Where appropriate copper would be included for ruminant health). The health messaging is simple: drink 250ml milk or milk product per day.

The current thinking is to use Bolus technology supplementation as this provides:
- Quality assurance. In the African context the dilution and counterfeiting of veterinary products is commonplace. The bolus technology is difficult to counterfeit.
- Bioavailability- The supplements are of known provenance and bio availability. Many mineral supplements, even if assured of the mineral levels can have poor bioavailability.
- Single 6 month dose. Bolus application can be given during the last trimester and lasts 180 days. This will supplement the peri natal calf and through until the cow is back in calf 3-4 months post calving. A second dosage may be needed if cows are milked beyond the 180 days.
- Compliance. As it is given in a single dose there is no need to give daily feed or supplement.

Approach

Research is required to pilot and monitor the

1. Literature Review on B12 and mineral status in human population in target country. Cultural review of meat consumption and lacto- vegetarian attitudes.Review of EFSA opinion on max levels and environmental effects (Zinc)

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[2] From our study, only cobalt levels were measured. In low cobalt animals the Cobalt in milk is present as as Vit B12. In supplemented animals or animals on a high Cobalt diet, other forms will be present in milk. In this study the animals were low in Cobalt, so the assumption is that it is only present as Vit B12. The conversion to Vit B12 (Suttle) is to multiply by 1355/58.9.Hence from this study the estimated Vit B12 levels of 2.3-34 ug/litre. (With a caveat on the higher figures)

2. Apply for grant funding
3. Develop multi phase trial design
4. Research collaborators in UK have been identified but roles. Collaborators in the target country need identified.
5. Roles and responsibilities and a Technical Board assigned.
6. Identify Ethics, Consent and GDPR permissions
7. Set up dairy fertility data collection and establish baseline
8. Confirm diagnostic testing to be used as nutritionalists, clinicians and vets use different diagnostics and different biochemical markers.
9. Confirm increase in B12 and iodine levels in milk from supplemented animals and confirm dosage of iodine to achieve 250 ug/ litre in milk.
10. Confirm samples to be used, analysis techniques and boundaries and cut offs for cows, fodder and people
11. Identify the likely populations of cattle and people for the study.
12. Recruit "One Health" extension workers.
13. Supplementation and monitoring over three years

Addendum

Vitamin A deficiency has been reduced but still affects almost half of African and South Asian children. This is in spite of the fact that the NIH recommended levels can be easily achieved by dietary changes to eating a daily portion of orange root vegetables -eg carrot/sweet potato and a portion of leafy greens -eg spinach.
Supplying sweet potato/carrot seed and cultivation advice alongside could be considered.