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HEALTH AND FOOD SAFETY CONCERNS OF EARLY DIETARY INTRODUCTION OF UNMODIFIED COW MILK TO INFANTS IN DEVELOPING COUNTRIES

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ABSTRACT

The timing of introduction of unmodified cow milk is critical in infant feeding. The objective of this review is to explore the underlying reasons for the early dietary introduction of unmodified cow milk to infant diets in the sub-Saharan African countries and also to assess the health and food safety concerns for its early introduction. Public health organisations including the American Academy of Paediatrics recommend that unmodified cow milk should not become part of infant diet before 12 months. Despite the recommendations and the evidence for an increased risk of multiple adverse health outcomes, the prevalence of early weaning and the early introduction of unmodified cow milk remain high in sub-Saharan African countries such as Uganda, Kenya and Ethiopia. Return to paid employment, inconsistent infant feeding advice from clinical professionals and maternal sickness are often the registered reasons by the mothers for the early introduction of breast milk substitutes. Therefore, parents should be educated on the health and food safety concerns of early introduction of unmodified cow milk. Unlike breast milk, unmodified cow milk does not provide a balanced diet for infants aged below 12 months. It contains excessive levels of protein, sodium, potassium, phosphorus, and calcium and insufficient levels of iron, vitamin C, and linoleic acid for human infant requirements. Consequently, the early introduction of unmodified cow milk is associated with risks of iron deficiency anaemia, protein-induced enterocolitis syndrome and increased renal solute load. Moreover, the introduction of unmodified cow milk into the infant diets should be delayed as long as possible to prevent the nutritional, health and food safety risks associated with its earlier introduction. It is also important that exclusive breastfeeding for 6 months in sub-Saharan African countries is promoted as it will extend breastfeeding benefits of prevention of iron deficiency anaemia and provide protection against infant nutritional childhood infections. Mothers should also be taught about proper infant feeding practices.

Key words: Infant health, unmodified cow milk

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INTRODUCTION

Infants should be exclusively breastfed for 6 months to achieve optimal growth and development. They should be given adequate nutritional benefits and safe complementary feeding from the age of 6 months with continued breastfeeding up to 2 years of age or beyond [1]. During the first year of life, an infant's birth weight is doubled by 6 months and tripled by 12 months, with an increase in length of 50%, a process that is not repeated at any other phase during the life cycle [2]. A nutritionally adequate diet is essential during infancy due to its impact on health and nutrition.

Unmodified cow milk is widely used as breast milk substitute in sub-Saharan African countries and it is often introduced into the infant diets earlier than recommended [3]. Public health organisations including the American Academy of Paediatrics recommend that unmodified cow milk should not be introduced to an infant's diet before the age of 12 months. Despite the recommendations and the evidence for an increased risk of adverse health outcomes, the early introduction of unmodified cow milk remains evident globally [4]. Approximately 30% of American infants are exposed to unmodified cow milk before the age of 12 months of age and the same proportion of infants are introduced to complementary foods before 4 months of age [5]. Similarly, a study by Siega-Riz *et al*., (2010) found that 17% of older infants aged 9 to 11 months were receiving cow milk before they reached 12 months [6].

A study in eastern Kenya found that by age of 3 months, 90% of infants were already receiving supplemental feedings of unmodified cow milk [3]. Similar timings about the early introduction of unmodified cow milk in the baby diets have been reported in other sub-Saharan African countries such as Ethiopia with evidence that the early introduction of unmodified cow milk before age 4 months is associated with malnutrition (particularly iron deficiency anaemia) [7]. Malnutrition undermines economic growth through direct loss of productivity because of diminished physical status, indirect loss from fragile cognitive development, and loss incurred due to increased health care costs.

The timing of introduction of unmodified cow milk into the infant diet is critical in infant health and nutrition. Unlike breast milk, unmodified cow milk does not provide a balanced diet for infants aged below 12 months. It contains excessive levels of protein, sodium, potassium, phosphorus, and calcium and insufficient levels of iron, vitamin C, and linoleic acid for human infant requirements [8]. Infants lack a fully developed digestive system to metabolise the nutrient load in the unmodified cow milk. Moreover, the daily nutrient requirements of a human infant are lower compared to those of a calf. The introduction of unmodified cow milk to an infant before the 12 months age can lead to increased renal solute load that leads to chronic constipation and anal fissures, increased blood loss from the gastrointestinal tract that contributes to iron deficiency and anaemia, and an increased risk for subsequent type 1 and 2 diabetes [8].

Return to paid employment is often the reason why mothers opt for the early introduction of breast milk substitutes in various parts of the world. For instance, a study in Taiwan found that return to work was a significant factor given by 12.7% of the mothers who never breastfed their infants [9]. Inconsistent infant feeding advice from clinical professionals also contributes to the early termination of exclusive breastfeeding [10]. Moreover, public health recommendations sometimes differ from the advice provided by clinical practitioners. For example, most public health organizations recommend breastfeeding for at least a year and the WHO guidelines suggest an even longer period [10]. Clinical professionals, specialized in infant nutrition are scarce in the hard to reach areas giving chance to other health professionals to offer divergent infant feeding information. A study by Engle *et al., in* eastern and southern Africa found that maternal sickness was also responsible for the early feeding of breast milk substitutes and solid foods. Poor health may hinder a mother's capacity to provide adequate nutrition for her family, as a function of either increased fatigue or reduced status in the households for women who are chronically ill [11].

In Uganda, the total milk production by the end of 2011 was between 1.6 billion to 1.8 billion litres of which total production, only 40% is processed, 45% is sold unprocessed and 15% is dumped [12]. However, of the 45% unprocessed cow milk that was sold in Uganda by the end of 2011, the portion of that milk that was introduced to the infants was not established and therefore, further research to establish how much unmodified cow milk is annually introduced to the infants at an age below 12 months in Uganda is necessary.

Public health risks associated with the early introduction of unmodified cow milk to infants in developing countries (sub-Saharan African countries)

The early introduction of unmodified cow milk to the infants at an age below 12 months is associated with public health risk of food protein-induced enterecolitis syndrome, type 1 and 2 diabetes, bovine tuberculosis, antibiotic resistance, among others. This section will discuss public health risks of significance and the health and food safety concerns associated with the early introduction of unmodified cow milk into the infant diets.

Food protein–induced enterocolitis syndrome

Strong research evidence associates unmodified cow milk feeding with food protein–induced enterocolitis syndrome. Cow milk protein allergy is the most common allergy in young infants with a 2- 6% incidence [13]. The main characteristic of cow milk protein allergy is the multiplicity and diversity of its allergens. Although the main allergens in cow milk protein seem to be found in the casein fraction and in *beta*-lactoglobulin, all milk proteins (of which there are approximately 35) appear to be potential allergens, even those present in trace amounts. Many infants present with gastrointestinal or skin symptoms (approximately 50- 60%), and respiratory symptoms are seen in about 30% of cases [14].

Type 1 diabetes

Auto-antibodies present at the age of 2 years strongly predict the type 1 diabetes disease [15]. Insulin is the only beta-cell-specific insulin auto-antibody (often appearing as the first autoantibody) and is associated with type 1 diabetes diagnosed in young children. Research evidence reveals that an insulin-induced immune response may be involved in the induction of autoimmunity [16]. The introduction of bovine insulin into the infant body through cow milk feeding particularly from consumption of infant formulas play a role in the early induction of beta-cell autoimmunity [17]. Bovine insulin is immunogenic and cross-reactive with human insulin and causes intolerance to human insulin [17].

Recent studies have shown that insulin auto-antibodies often preferentially bind to non-human insulin from unmodified cow milk and a portion of insulin auto-antibodies is of the Immunoglobulin A class suggesting its mucosal origin [18]. This hypothesis may well explain the association of short exclusive breastfeeding and early cow milk exposure in infancy with the development of diabetes-associated autoimmunity [19]. Similarly, case-control studies conducted on a Chinese population in Taiwan found that there was approximately one and a half-fold increased risk of type- 1- diabetes associated with decreased breastfeeding duration and feeding of unmodified cow milk to infants before 3 months [20].

Bovine tuberculosis

More than 8 million people are infected with bovine *Mycobacterium*- induced tuberculosis globally and over 1.6 million people die from tuberculosis annually [21]. In Uganda, 402 new cases of tuberculosis per 100,000 people were reported in 2005 particularly in pastoral communities that live in extremely close contact with their animals and consume raw milk forming as part of their daily diet [21]. Consumption of unpasteurised (unmodified) cow milk is associated with bovine tuberculosis. In Ethiopia for example, where bovine tuberculosis is still common and pasteurisation of milk is not practised, an estimated 10–15% of human tuberculosis is caused by *Mycobacterium bovis* [22]. Moreover, a recent outbreak of bovine tuberculosis in Ireland was as a result of the consumption of unpasteurised milk [23].

In China, there is a very low proportion of bovine tuberculosis cases in patients that come from districts where milk is pasteurised, with a much higher proportion being reported in pastoral areas where raw milk is consumed thus supporting the hypothesis that human bovine tuberculosis is primarily a food-borne disease [24]. Ethiopia has been identified as a country where the impact of bovine tuberculosis is particularly important and one of the African countries with the highest burden of human tuberculosis cases [25].

The prevalence of bovine tuberculosis in Ethiopia is high ranging from 3.4% in smallholder production systems that keep Zebu (local) cattle to 50% in semi-urban (intensive) dairy production systems [26]. The high prevalence of tuberculosis in cattle, the close contact of cattle and humans in rural areas, the habit of consuming

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raw milk within the community and the increasing prevalence of human immunodeficiency virus (HIV) may all increase the potential for transmission of *Mycobacterium tuberculosis* and other mycobacteria between cattle and their owners. The proportion of bovine TB infection resulting from raw milk consumption as a single confounding factor in Ethiopia hasn't been established and more studies therefore are needed to quantify this problem. Moreover, similar studies undertaken in Madagascar (n=400) recorded a prevalence (1.25%) of *mycobacterium bovis* from sputum smear-positive human tuberculosis patients and similar results of isolated *Mycobacterium tuberculosis* from milk have also been reported in Nigeria [27].

Iron deficiency anaemia

Anaemia is a major public health problem in developing countries, particularly for pregnant women and young children. Anaemia is defined as haemoglobin levels less than 11 grams/decilitre and it has substantial variability in prevalence between countries [28]. Approximately 47% of children below 5 years of age in developing countries are anaemic. In eastern Uganda, 40% of children below the age of 5 years suffer from iron deficiency anaemia [29]. The anaemia situation is aggravated by high prevalence of malaria, hookworm infection, and schistosomiasis and sickle cell anaemia. Anaemia is also high among pregnant and lactating women. Iron deficiency anaemia occurs in 50% of Ugandan pregnant women and about 30% of maternal deaths are attributable to iron deficiency anaemia [30]. Childhood anaemia has been linked to serious health consequences, including impairments in cognitive function, physical development, psychomotor development, and language development [30]. Severe anaemia (haemoglobin levels less than 5 grams/decilitre) is associated with an increased risk of infant mortality [31].

Vulnerable populations should be encouraged to consume iron-rich foods (for example, red meat and liver), breastfeed and/or use iron-fortified formula for infants in order to prevent iron deficiency. Cow milk and other dairy products obtained from cows (being very rich in calcium and casien), the high calcium and casien fractions in the cow milk form complexes with iron making it unavailable for the infant body's digestion and absorption. Cow milk also contains insufficient levels of iron, vitamin C yet vitamin C is an essential co-factor in iron metabolism. The high fractions of calcium and casein and the low levels of vitamin C and iron in cow milk are thus responsible for the high prevalence of iron deficiency and anaemia in infants in sub-Saharan African countries. Consumption of unmodified cow milk during the first year of life and delaying the introduction of iron-rich solid foods after 6 months of age were found to be important predictors of iron deficiency anaemia [32].

Antimicrobial agent residues

Residues of antimicrobial agents (antibiotics) used in animal health practice can be detected in various animal tissues for some duration following therapy. They are usually attributed to non-observance of withdrawal periods before sale of animal source foods or feeding feeds contaminated with antimicrobials or direct addition of antimicrobial agents to preserve milk [33]. Drug residues are of concern to human health due to their association with varying degrees of allergies ranging from mild skin rashes to *angio*-oedema and life-threatening anaphylaxis and drug resistance [34]. Moreover, investigations from Hyderabad State (India) found 9% of the marketed bulk milk samples and as high as 73% of milk samples obtained from individual animals at farm level had oxytetracycline residues, which perhaps indicates some dilution effect of bulking on residue concentration [35].

Similar studies have reported the presence of penicillin residues up to 3% of bulk milk supplied to Johannesburg, South Africa [36]. More recent studies in Kenya found a higher prevalence of antimicrobial residues in milk and meat samples with 11% of raw bulk milk samples sold in Nakuru (Kenya) containing penicillin-G residues [37]. Similarly, a milk quality assessment study on milk produced and sold in Bamako, Mali found that 6% of raw milk contained antibiotic residues [38]. The same study attributed the poor milk quality to the low level of the local production, antibiotic residues, brucellosis, subclinical mastitis, milk adulteration and unclean milk containers [38]. It is therefore imperative that animal welfare and health, milk safety and quality testing for antimicrobial agent residual testing is done to reduce the risks of antibiotic resistance, childhood cancers and child morbidity.

Mycotoxins and enterotoxins

Mycotoxins are secondary metabolites produced by moulds and fungi that are common contaminants of agricultural commodities [39]. The major classes of mycotoxins affecting feedstuffs include aflatoxins, egotism, deoxynivalenol and zearalenone, mainly occurring in corn and in concentrated feeds ingredients [39, 40]. Mycotoxins are capable of altering immune-mediated activities, producing acute toxic, carcinogenic, mutagenic, teratogenic and estrogenic effects in humans depending on the level of exposure and dosage [41]. Mycotoxins, such as aflatoxins, can also be transferred to milk when the animals are fed on corn contaminated with mycotoxins and its presence in milk is undesirable. The occurrence of mycotoxins in dairy products and mainly in milk makes it a particular risk for humans because of their negative effects in foodstuff for humans and particularly children [42].

Staphylococcus aureus, is one of the important causes of food-borne diseases in humans, but is commonly associated with intoxications due to its ability to produce a variety of potent enterotoxins [43]. Enterotoxins are respon,sible for food poisoning and childhood cancers that are on the rise globally. *Stapylococcus aureus* can be destroyed through heat treatment when present in milk and other food products. Although heat may kill *Staphylococcus aureus* cells, the enterotoxin may persist in food since it is more heat stable than the micro-organism [44]. In animals *Staphylococcus aureus* is the most frequent causative agent of mastitis, especially in cattle, sheep and goats and this makes it a common contaminant of raw milk [45]. However, from the infant nutrition point of view, it is important that the animals are feed on mycotoxin-free corn to prevent food poisoning of the infants.

Microbial contamination

The detection of coliform bacteria and pathogens in milk indicates a possible contamination of bacteria either from the udder, milking utensils or water supply used. Fresh milk drawn from a healthy cow normally contains a low microbial load (less than 1000 per millilitre), but increases up to 100-fold or more once it is stored for some times at room temperatures [46]. In some countries, the legal limits for viable bacteria in pasteurised milk range from $5×10^3$ to $5×10^4$ colony forming units/millilitre [47]. The minimum accepted bacterial limit for raw milk in Zimbabwe is $5×10^5$ colony forming units/millilitre [48]. Although microbial contamination has proven to be a challenge in smallholder dairies, especially for sub-Saharan African countries like Zimbabwe, the lack of milk standards and cooling facilities greatly affect the microbial quality of milk. It is therefore necessary that the microbiological quality of milk and milk products be determined in order to monitor milk safety. Also, the introduction of unmodified milk to infants in such regions should be delayed for at least 12 months and breastfeeding promoted.

The handling of milk in clean containers and at refrigerated temperatures immediately after the milking process may delay the increase of initial microbial load and prevent the multiplication of microorganisms in milk between milking at the farm and transportation to the processing plant [49, 50]. Keeping fresh milk at elevated temperatures and the use of unhygienic practices in the milking process, results in microbiologically inferior milk quality. A quality assessment study (n=930 milk samples) in Malaysia found that 33.5% of the samples tested positive for *E. coli* 0157:H7. The incidence of *E. coli* 0157:H7 in raw milk samples collected from the central region was the highest (39%), followed by samples from eastern and northern regions with prevalence of 37% and 36%, respectively [50].

Over 90% of all reported cases of dairy related illness continue to be of bacterial origin, with at least 21 milk-borne or potentially milk-borne diseases being recognized [51].The pathogens that have been involved in food-borne outbreaks associated with the consumption of raw milk include *Listeria monocytogenes, Salmonella, Campylobacter, Staphylococcus aureus, Bacillus cereus* and *Clostridium botulinum*. Moreover, the presence of these pathogenic bacteria in milk is of major public health concerns, especially for those individuals who still drink raw milk. Most recently, *E.coli* 0157:H7 has become a serious threat to the dairy industry with several outbreaks reported in developed countries ranging from mild diarrhoea to potentially fatal haemolytic uremic syndrome, and hemorrhagic colitis [52].

The detection of *E. coli* reflects faecal contamination of water and foods such as milk and dairy products. *E. coli* is a commensal micro-organism of the intestines of animals and humans but its recovery in food is of public health concern due to the possible presence of entero-pathogenic and/or toxigenic strains. *Entero*-pathogenic *E. coli* strains can cause severe diarrhoea and vomiting in infants and young children while toxigenic strains like *E. coli* O: 157:H7 cause haemolytic and uremic syndrome [53]. Diarrheal diseases are among the leading causes of death among infants in developing countries and claimed an estimated 1.4 to 2.5 million lives in the year 2000 [54].

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CONCLUSIONS AND RECOMMENDATIONS

Unmodified cow milk remains a widely used breast milk substitute in developing countries particularly the sub-Saharan African countries. It is introduced much earlier into the infant diets than the 12 months that are recommended by the public health organisations. Early return to paid employment and maternal sickness are some of the factors responsible for the early introduction of unmodified cow milk into the infant diets. Cow milk contains high fractions of calcium, casein and low levels of iron and vitamin C that greatly affect the body's ability to metabolise and absorb iron and other micronutrients leading to iron deficiency and anaemia in infants. Unmodified cow milk is also a potential source of pathogenic bacteria, antibiotic agent residues, mycotoxins and *Mycobacterium bovis* that causes bovine TB in infants. It is therefore important that the introduction of unmodified cow milk into the infant diets is delayed as long as possible to prevent the nutritional, health and food safety concerns associated with its earlier introduction. The parents should be educated on the health and food safety concerns of early introduction of unmodified cow milk. It is also important that exclusive breastfeeding for 6 months in sub-Saharan African countries is promoted as it will extend breastfeeding benefits of prevention of iron deficiency anaemia and provide protection against infant nutritional childhood infections. Mothers should also be taught about proper infant feeding practices.

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