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Abstract

Purpose – Inadequacies in several micronutrients in complementary foods, notably iron, zinc, calcium, vitamin A, vitamin B6 and riboflavin have been reported. *Moringa oleifera* leaf powder (MLP), prepared from dried *moringa* leaves is nutrient-rich and has been explored for the treatment of micronutrient deficiencies among children in developing countries. This increasing interest in the use of *moringa oleifera* leaves to improve complementary foods notwithstanding, the unique sensory characteristics of the leaf powder potentially holds implications for the acceptability of local diets that are fortified with it. The purpose of this paper is to investigate the levels of MLP fortification that are most acceptable for feeding infants and young children.

Design/methodology/approach – The authors performed a review of the literature, with the aim of investigating the sensory attributes and acceptable levels of fortification of complementary food blends fortified with different levels of MLP.

Findings – The minimum amount of MLP to be added to a complementary food blend to observe significant improvements in its nutritional value was estimated to be about 10 per cent. However, at this 10 per cent fortification level also, sensory attributes of the products begin to become less desirable.

Practical implications – For the success of nutrition interventions that involve the use of MLP to improve the nutritional quality of complementary foods, there is a need to consider the acceptability of the sensory attributes of the formulated blends in the target group. Safety of MLP as an ingredient in infant foods must also be investigated.

Originality/value – The authors of this paper make recommendations for the use of MLP to fortify complementary foods to ensure its success as a food fortificant in nutrition interventions. The researchers are not aware of any published study that focuses on this subject.

Keywords Malnutrition, Micronutrients, Acceptability, Complementary foods, Moringa oleifera leaf powder

Paper type Literature review

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Introduction

Inadequate intake of micronutrients is recognized as an important contributor to the global burden of disease through increased rates of illness and death from infectious diseases and of disability such as mental impairment (Black, 2003). Deficiencies of vitamin A, iron, iodine and zinc among children are the most devastating in terms of impaired development and mortality (Hall *et al.*, 2001). UNICEF (2016) reports that millions of children suffer from stunted growth, cognitive delays, weakened immunity and disease as a result of micronutrient deficiencies. Vitamin A deficiency affects about one-third of children living in low- and middle-income settings, mainly in sub-Saharan Africa and South Asia and more than 40 per cent of children under five in developing countries are anaemic (UNICEF, 2016). In Ghana, the recent Demographic and Health Survey report indicated that 19 per cent of the infants and young children under five years of age in Ghana are stunted and 5 per cent are wasted, whilst 66 per cent of them have varying forms of anaemia (Ghana Statistical Service, 2015). Thus, undernutrition continues to be a challenge that needs to be addressed.

In developing countries, complementary foods that are deficient in both macronutrients and micronutrients coupled with a high burden of infections during complementary feeding period (from age 6-24 months) are major underlying causes of child malnutrition (Dewey and Vitta, 2013).

Inadequacies in several micronutrients in complementary foods, notably iron, zinc and calcium, vitamin A, vitamin B_6 and riboflavin, have been reported (Gibson, 2011).

In the rural settings of Ghana (and much of West Africa), porridge prepared from unrefined cereals such as maize, millet or sorghum is usually the first complementary food. These unrefined cereals have high levels of anti-nutrients which inhibit the absorption of micronutrients, thus resulting in malnutrition (Amagloh *et al.*, 2012).

Improving the quality of diets of infants and young children during the complementary feeding period is one of the most cost-effective strategies for improving health and reducing morbidity and mortality (Krebs and Hambidge, 2007). Two main ways to provide additional nutrients to this target group of young children (6-23month) are fortification and supplementation (de Pee and Bloem, 2009). Distribution and sustainability of supplementation programmes, however, remain an issue in poor resource settings. Thus, food-based approaches including fortification, improving dietary quality through diversification/modification and nutrition education and bio-fortification are increasingly being pursued (Gibson, 2011). Fortification can be carried out in different ways, including home fortification, where a small amount of powder or spread is added to a home-prepared meal (de Pee, 2015). Dewey and Vitta have proposed the promotion of increased intake of key nutrients from local foods, including certain indigenous foods that are currently under-utilized as complementary foods, to ensure adequate nutrient intake among infants and young children (Dewey and Vitta, 2013). *Moringa oleifera*, one such edible plant, has been shown to be a rich source of micronutrients that could be included in infant complementary foods. *Moringa oleifera*, *Lam (Syn M.pterygosperma Gaertn)* usually referred to in the literature as *Moringa*, is naturally occurring, as well as a cultivated variety of the genus *Moringa* belonging to family *Moringaceae*. *Moringa oleifera* is the most widely cultivated pan-tropical species of the *Moringaceae* family, which is native to the sub-Himalayan tracts of India, Pakistan, Bangladesh and Afghanistan, and is known by such regional names as benzolive, drumstick tree, *kelor, marango, mlonge, mulangay, nébéday, saijhan and sajna* (Dhakar *et al.*, 2011). *Moringa* is a drought-tolerant tree that tolerates a wide range of environmental conditions (Saint Sauveur, 2001). The leaves, pods, seeds, gums, bark and flowers of *moringa* are reportedly used in more than 80 countries to treat mineral and vitamin deficiencies, support a healthy cardiovascular system, promote normal bloodglucose levels, neutralize free radicals, provide excellent support of the body's anti-flammatory mechanisms, improve anaemia and support the immune system (Mahmood *et al.*, 2010). Several reports on the nutritional qualities of *moringa* currently exist in both the scientific and the popular literature, and virtually, every part of the tree is beneficial in some way to both rural and urban populations (Dhakar *et al.*, 2011). Several studies have investigated the nutrient content of *Moringa oleifera* leaves in particular (Asante *et al.*, 2014; Garba *et al.*, 2015; Moyo *et al.*, 2011), with impressive results with respect to its nutritional potential. Available data suggest that the leaves contain highly digestible proteins and are rich in vitamin A, iron, calcium, vitamin C and other carotenoids (Dhakar *et al.*, 2011). The leaves have also been explored for the treatment of micronutrient deficiencies among children in Malawi and Tanzania (Babu and Rajasekaran, 1991; Rweyemamu, 2006).

Glover-Amengor *et al.* (2017) reported that the leaves of *Moringa oleifera* could be harvested and cheaply dried with solar dryers and milled to form a powder that could be stored for use in rural households. In some developing countries, there is currently an increasing interest in the use *of Moringa oleifera* leaf powder (MLP) to fortify complementary foods, and several studies have reported a marked improvement in the nutrient composition of complementary foods fortified with MLP (Steve and Babatunde, 2013; Isingoma *et al.*, 2015; Odinakachukwu *et al.*, 2014; Shiriki *et al.*, 2014). This increasing interest in the use of *Moringa oleifera* leaves to improve complementary foods, notwithstanding the unique sensory characteristics (colour, taste and odour) of the leaf powder potentially holds implications for acceptability of local diets that incorporate the leaf powder.

Food acceptance plays a crucial role in the success of nutrition interventions that seek to introduce new food commodities (Babu and Rajasekaran, 1991). For a nutrition intervention to be successful, most consumers in the target populations (in this case infants and young children) must accept and consume the food commodities in quantities sufficient to improve their nutritional health (Miller and Welch, 2013). Oyeyinka and Oyeyinka (2018) have, however, reported in their review paper which focuses on *moringa* as a food fortificant that, the acceptability and sensory characteristics of foods decrease with increasing MLP supplementation. Children who are the target of complementary feeding interventions have been shown to like sweet tastes and dislike bitter tastes and tend to eat more of foods they like (Drewnowski, 1997). The above findings give an indication that, despite their improved nutritional quality, increasing levels of MLP could reduce the acceptance of MLP-fortified foods (Gebretsadikan *et al.*, 2015) and potentially affect the success of MLP complementary feeding nutrition interventions. Thus, the authors of this paper reviewed the literature on the sensory evaluation of complementary foods fortified with MLP, with the aim of investigating the levels of fortification that are most acceptable for feeding infants and young children.

Methods

A search in Google Scholar was performed with keywords such as "*Moringa Oleifera* leaf powder", "complementary food", "acceptability", "sensory evaluation" and "malnutrition". The bibliographies of the articles on hand were used to find other references. Studies that formulated complementary food blends for infant porridges using MLP as a fortificant and further investigated the sensory profile/acceptability of the formulated foods were included in the study.

The authors identified seven studies (including one study that used *Moringa stenopetala*) that focused on the sensory evaluation of complementary foods that had been formulated with MLP. The details of the seven studies are summarized in Table II. Eight other studies which reported the sensory profiles of other food products like bread and cookies which could potentially be used as complementary foods for older infants were also identified and included in the review (Table III).

Nutritional potential of MLP in complementary foods

Moringa oleifera has been given a lot of attention as a nutrient source and has been studied more than many other plants (Witt, 2013). The leaves, fruit, flowers and immature pods of this tree are used as a highly nutritive vegetable in many countries, particularly in India, Pakistan, Philippines, HI and many parts of Africa (Mishra *et al.*, 2012). The dried leaves in particular are concentrated sources of valuable nutrients and can be cheaply produced and stored for use in low-resource settings (Glover-Amengor *et al.*, 2017). Dewey *et al.* (2009) have also reported that home fortification of complementary foods, also referred to as "point-of-use" fortification, is a promising strategy that is able to deliver the appropriate amount nutrients for children 6-24 months without making major alterations to their diet (Dewey *et al.*, 2009). MLP is a nutritious product that can be used at home to fortify the diets of infants and young children. Virtually, all children are introduced to some kind of porridge when they start complementary feeding, often based on the local staple food. Thus, safely produced and fortified porridges can fit well with existing food consumption practices and enable feeding of an adequately nutritious meal to children (de Pee and Bloem, 2009). There has been a recent interest in the promotion of MLP as a nutritionally valuable ingredient in complementary foods (Isingoma *et al.*, 2015; Odinakachukwu *et al.*, 2014; Shiriki *et al.*, 2014; Steve and Babatunde, 2013). Witt (2013) pooled together the findings of several studies that investigated the nutritional value of MLP and determined the contribution of 5 g of the product to diets of children aged 1-3 years, a summary of which is reported in a Table I. The study found a wide variability in the nutrient content of both the fresh and dried leaves and recommended that nutrition intervention studies that intended to include *Moringa oleifera* as part of supplemental feeding programs, need to analyse samples periodically throughout the program to ensure that planned nutrient targets are being met continuously (Witt, 2013).

Sensory characteristics of MLP

Recent studies have mainly focused on the nutritional quality of *Moringa oleifera* leaves, regardless of the complexity of the food matrix of recipes in which they are involved (Mawouma *et al.*, 2017). Sensory responses to the taste, smell and texture of foods help determine food preferences and eating habits (Drewnowski, 1997). A recent study by Ramaroson *et al.* (2015) investigated the role of languages in consumers' description of six samples of *Moringa* leaf powder sourced from five regions in Malaysia. The authors of the study required two groups of assessors (each group spoke a different language) to spontaneously generate descriptors for the appearance, taste and aroma/flavour of MLP among other sensory attributes. The descriptors for appearance generated by both groups included "green", "yellow" and "dried leaves". Descriptors generated for taste included "bitter", "tasteless", "sour", "astringent", "hot", "aftertaste", whilst descriptors generated for odour/aroma included "dry leaves", "cassava leaves", "raw", "acid", "dryfish/shrimp" and "fermented/rotten"(Ramaroson *et al.*, 2015). This study gives an indication of generally undesirable descriptions of the sensory attributes of MLP, and these attributes are conferred onto products to which MLP is added. This review focused on seven studies that investigated the sensory profiles of complementary food blends fortified with MLP (Table II). Specifically, the sensory characteristics of flavour and colour are highlighted.

Table I. [A] Contribution of Fresh and dried *moringa oleifera* leaves to the nutrient needs of children aged 1-3 years

Nutrient	Nutrient content of *Moringa oleifera* 5 g (1 Tbsp) *Moringa* leaf powder	20g (1 cup) fresh *Moringa* leaves	Recommended nutrient intake 1-3-year-old children	(%) of recommendation provided 5 g (1 Tbsp) *Moringa* leaf powder	20 g (1 cup) fresh *Moringa* leaves
Energy (kcal, MJ)	15.2 kcal, 0.064 MJ	17.3 kcal, 0.072 MJ	1,098 kcal, 4.6 MJ	1	2
Protein (g)	1.2	1.76	13	9	14
Fibre, total dietary (g)	2.0[B]	1.3[B]	19	11	7
Ca (mg)	95	106[B]	700	14	15
Mg (mg)	23.65[B]	5.2-30.2[B]	80	29	6.5-38
Fe (mg)	1.625[B]	2.16	7(14)[C]	23(12)[C]	31(15)[C]
Zn (mg)	0.12	0.06-0.26[B]	3(6)[C]	4(2)[C]	2(1)[C]
Thiamine (mg)	0.13[B]	0.05[B]	0.5	26	9
Riboflavin (mg)	0.06-1.0[B]	0.15[B]	0.5	12-200	29
Niacin (mg)	0.41[B]	0.74[B]	6	7	12
Vitamin B6 (mg)	0.12[B]	0.24[B]	0.5	24	48
Folate (μg)	27[B]	41	150	18	27
Vitamin A (μg, RAE)	182[B]	258	300	61	86
Vitamin C (mg)	8.6	32.4	15	57	216
Vitamin E (mg)	2.8-5.6[B]	5	6	46-93	83

Notes: [A]Table used with permission from Witt, 2013; [B]for these nutrients, the amount of data were limited or data were highly variable; [C]the value provided in parenthesis is for vegetarians

Flavour of complementary foods formulated with MLP

Flavour, an important component in the acceptance of foods, is a combination of the senses of taste, aroma and mouth feel (Singh-Ackbarali and Maharaj, 2014). Taste is an important influential factor in a person's selection of a particular food. Clark cites a study that investigated infants' reactions when they were given solutions of sweet and bitter compounds. In this study, Clark notes that, in response to tastes that were sweet, children exhibited a facial acceptance response that included large eyes and a retraction of the mouth, in such a manner as to resemble a smile (Clark, 1998). Bitter tastes, however, elicited an entirely different response with infants tightly shutting their eyelids, gaping at the mouth and suddenly turning their heads, indicative of dislike for the taste of the test food (Clark, 1998). Clark concluded from these findings that, from an early age, human behaviour towards foods seems to be strongly influenced by the effects of taste and flavour (Clark, 1998). In six of the seven studies presented in Table II, the mean scores for taste were inversely related to the *moringa* levels in the porridges (Abioye and Aka, 2015; Gebretsadikan *et al.*, 2015; Olaitan *et al.*, 2014; Olorode *et al.*, 2013; Ukey *et al.*, 2014; Ntila *et al.*, 2018). Olorode *et al.* (2013) attributed this trend to the "leafy taste" of MLP, Gebretsadikan *et al.* (2015) attributed it to the "herbal flavor" of MLP, whilst Ntila *et al.* (2018) attributed it to the "bitter taste" of porridges to which MLP had been added.

Colour of complementary foods formulated with MLP

Extensive research has confirmed the importance of colour in taste recognition and intensity, flavour detection and recognition and in food preference and food acceptability (Imram, 1999). Colour is a strong indicator of the acceptability of a product because a small

Table II.
Summary of sensory evaluation studies of complementary food blends fortified with MLP

No.	Country/ Authors	Year	Ingredients and description of complementary foods to which MLP was added	Description of sensory panel	Use of control (0% MLP)	MLP fortification range (%)	Fortification level for overall least acceptable MLP formulation (%)	Fortification level for overall most acceptable MLP formulation (%)	Authors' recommendation of acceptable MLP fortification levels (%)
1	Nigeria/ Abioye and Aka	2015	Fermented maize flour, used to make a porridge called "*Ogi*"	Trained panel of 10 university students	Yes	10-15	15	10	10
2	Nigeria/ Olorode *et al.*	2013	Fermented maize flour, used to make a porridge called "*Ogi*"	Panel of 50 university staff and students	Yes	5-25	25	5	10
3	Nigeria/ Olaitan	2014	Millet flour, used to make a porridge	Semi-trained panel of 14 mothers	Yes	2.5-10	10	2.5	Not reported
4	India/ Ukey	2014	Soybean flour and barley flour used to make a weaning food	Not reported	Yes	5-15	15	5	5
5	* Ethiopia/ Gebretsadik-an	2015	Orange flesh sweet potato and soybean flour composite, used to make porridge	Untrained panel of 50 town residents	No	5-10	10	5	5-8
6	Ghana/ Boateng *et al.*	2	Porridges made from cereal–legume blends	Semi-trained panel of 36 infant and caregiver dyad	No	10-15	10	15	15
7	South Africa/ Ntila *et al.*	2018	Porridges made from maize meal	Panel of 120 caregivers of children aged 7-12 months	Yes	1-3	1	3	1

Notes: *This study used *Moringa stenopetala* for fortifying the complementary food blend. w/w – weight by weight improvement in colour rating can result in a big difference in the acceptability of the product (Gebretsadikan *et al.*, 2015).

In the studies presented (Table II), the deep green colour of the porridges resulting from the addition of *moringa* leaf powder was reported to be one of the underlying reasons for the decrease in acceptability of the formulated foods, as the levels of MLP increased. Olorode *et al.* (2013) reported that the green colour is contrary to the normal white or yellow colour of maize "*Ogi*", whilst Gebretsadikan *et al.* (2015) reported that an increase in the proportion of *moringa* led to poor acceptability due to the amplification of unfamiliar green colour of the porridge.

Overall acceptability of complementary foods formulated with MLP

As with the other sensory attributes, the overall acceptance was inversely related to MLP levels in the porridges in majority of the summarized studies. The MLP fortification levels of the complementary foods ranged from 1 to 25 per cent. The most acceptable levels of fortification ranged from 1 to 15 per cent, with three out of the five studies reporting 5 per cent fortification level as the most acceptable. The least acceptable fortification levels ranged from 3 to 25 per cent. The authors recommended a fortification level of between 1 and 15 per cent for the formulation of an acceptable product. Each of the studies (with the exception of the study by Boateng *et al.*, 2017) used a control porridge which had 0 per cent MLP. The sensory characteristics of MLP-fortified porridges differed markedly from the controls as fortification of MLP increased. The summarized studies (Table II) appear to give an early indication that the minimum amount of MLP to be added to a product to observe significant improvements in its nutritional value is about 10 per cent. However, at this 10 per cent fortification level also, the sensory attributes of the products begin to become less desirable.

Acceptability of other foods fortified with MLP

Baked snack foods such as bread and cookies are widely consumed in every part of the world and have become an attractive target for feeding and nutrition improvement programmes among low-income groups and disaster-relief agencies (Mouminah, 2015). Table III summarizes the results of sensory evaluation studies that involved the fortification of these products with MLP. Similar trends were observed for these foods as with the complementary food blends. An exception was the study by Premi and Sharma (2014) in which fortified cookies with MLP at 0, 10, 20 and 30 per cent were subjected to organoleptic evaluation. The cookies fortified with 20 per cent MLP were found to be most acceptable in terms of appearance, taste, texture and overall acceptability even when compared to all the other formulations, including the control. This finding was inconsistent with the other reported studies (Table III). In spite of the inverse relationship between MLP fortification levels and sensory attributes of the food products, all the studies presented (Dachana *et al.*, 2010; El-Gammal *et al.*, 2016; Kar *et al.*, 2013; Manaois *et al.*, 2013; Mouminah, 2015; Odinakachukwu *et al.*, 2014; Premi and Sharma, 2014), with the exception of the study, recommended the inclusion of MLP at various levels in formulating the food products, because of the nutritional benefits. Sengev *et al.* (2013), however, concluded that, despite the high nutrient content of *Moringa oleifera* powder, it is not a good substitute for wheat in bread production due to the reduction in its physical characteristics and sensory attributes.

The way forward

The use of uncommon crops like the leaves of *Moringa oleifera* for complementary food fortification would have an impact on their sensory attributes and may be difficult to accept

Table III. Summary of sensory evaluation studies of other food items fortified with MLP

No.	Country/ Authors	Year	Ingredients and description of complementary foods to which MLP was added	Description of sensory panel	Use of Control (0% MLP)	MLP fortification range (%)	Fortification level for overall least acceptable MLP formulation (%)	Fortification level for overall most acceptable MLP formulation (%)	Authors' recommendation of acceptable MLP fortification levels (%)
1	Egypt/ El-Gamal	2016	Wheat flour, used to bake pan bread	Panel of 15 university staff members	Yes	5-20	20	5	5-10
2	Nigeria/ Sengev	2013	Wheat flour, used to bake bread	Not reported	Yes	1-5	5	1	Not reported
3	India/ Dachana *et al.*	2010	Wheat flour, used to bake cookies	Trained panel of 16 baking technologists	Yes	5-15	15	5	10
4	India/ Kar *et al.*	2013	Wheat flour used to bake biscuits	Panel of 20 university staff members	Yes	*5 – one fortification level only	–	–	5
5	Saudi Arabia/ Mouminah	2015	Wheat flour, used to bake cookies	Panel of 10 judges	Yes	5-15	15	5	10
6	India/ Premi	2014	Wheat flour, used to bake cookies	Trained panel of 10 judges	Yes	10-30	10	20	20
7	Pakistan/ Nadeem	2013	Whey-based drink	Trained panel of 10 judges	Yes	1-5	5	1 and 2	4
8	Philippines/ Manaois *et al.*	2013	Rice flour used to make rice crackers	36 grade-six pupils 11-12 years 30 staff of a rice company	Yes	1-5	5	1-2	1-2

in the short term because of the tendency to adopt specific crops for porridge processing by any given community (Gebretsadikan *et al.*, 2015). The findings of this review indicate that, despite the high nutrient content of MLP, it may not be successful in improving the nutritional status of infants in low-resource populations, if the new foods are not accepted by the target consumers. The authors thus make a number recommendations for consideration in the use of MLP to fortify complementary foods:

- The need for acceptability trials: Acceptability of complementary food blends fortified with MLP will need to be investigated with extensive acceptability trials that include a component where mothers are required to feed the formulated products to their children under home conditions for extended periods. Wardle *et al.* (2003) have reported that repeated exposure to the taste of unfamiliar foods is a promising strategy for promoting liking of previously rejected foods in children. Considering the uniqueness of the sensory attributes of MLP complementary food blends, one-time sensory or organoleptic evaluations may not be enough to determine the acceptability of the fortified foods.
- In this review, it can be observed that, although the formulated complementary foods were intended for infants and young children, majority of the panels that took part in the sensory evaluation were adults. Furthermore, only three of the seven studies reported (Olaitan *et al.*, 2014; Boateng *et al.*, 2017 and Ntila *et al.*, 2018) used panels of mothers and infant caregivers, (the most appropriate population to determine the acceptability of complementary food), for the sensory evaluation. The study by Boateng *et al.* (2017), which is the only study that included infants on the sensory panel, concluded that MLP used either as part of a formulated cereal–legume blend or as a supplement which was added to infants' usual diets were well accepted by infants and their caregivers in the population studied (Boateng *et al.*, 2017). More rigorously designed acceptability trials involving mother–infant pairs and lasting for extended periods are urgently needed to help ascertain the minimum levels of incorporation of MLP that will be both acceptable and nutritionally beneficial to the target population.
- Exploring the use of alternative forms of the formulated foods such as fermented products; a study by Isingoma *et al.* (2015) aimed to improve the nutritional value and safety of finger millet porridges using *Moringa oleifera*, *Cucurbita maxima* and lactic acid fermentation. Two types of porridge products were produced (one type fermented and the other unfermented) and subjected to sensory analysis. The results of the study indicated that majority of the mothers preferred the flavour of fermented porridges to non-fermented porridges. Mothers also showed higher preference in taste, colour and acceptability of fermented *Moringa oleifera*- and *Cucurbita maxima*-fortified finger millet porridges than the non-fermented ones. It will be beneficial to ascertain this finding by conducting further studies, as this may be an alternative way of improving the acceptability of *moringa*-fortified porridges. The effect of fermentation on the nutritional quality of the MLP-fortified foods must also be investigated.
- Exploring the incorporation of MLP in other types of foods aside porridges; the authors of this review recommend that, to extend the nutritional benefits of MLP, the use of other dishes in which the leaf powder can be added in substantial quantities without adversely affecting the sensory attributes should be explored. Glover-Amengor *et al.* reported that, in a rural community in Ghana, *Moringa*

oleifera leaves are eaten mostly in stews and soups (Glover-Amengor *et al.*, 2017). These and other yet-to-be-explored food alternatives fortified with MLP may be more acceptable to infants and young children than complementary food blends.

- Incorporation of dietary components that will enhance the sensory attributes of the MLP-fortified complementary food blends is another option that can be explored; the study in Ethiopia (Table 2) that aimed to develop nutritionally enriched and palatable complementary food products for Ethiopian mothers from orange flesh sweet potato (OFSP), soybean and *moringa* leaf powder blends found that, in general, the fortified porridges processed from high OFSP and/or soybean proportions with less *moringa* received the highest overall acceptability products (Gebretsadikan *et al.*, 2015). In this review also, the overall acceptance was inversely related to *the moringa* levels in the porridges. However, the researchers reported that the acceptability of *moringa*-fortified food products could increase with OFSP supplementation because of its sweet nature that has a masking effect on the undesirable taste and odour of the MLP-fortified products (Gebretsadikan *et al.*, 2015).
- Using other parts of the *Moringa oleifera* plant. A study in Nigeria that explored the use of *Moringa oleifera* flower powder in the fortification of complementary foods showed that the proximate composition and organoleptic properties of cereal such as maize, millet and others could be enhanced through the addition of flour made from the flowers of *Moringa oleifera (*Arise *et al.*, 2014). In this study, the ratings for the taste and flavour increased with increasing level of inclusion of *Moringa oleifera* flower powder *(*Arise *et al.*, 2014), contrary to what is observed for the MLP-fortified foods. These findings indicate that the flower powder could be used instead of the leaf powder to fortify complementary food blends.
- Safety of MLP as an ingredient in complementary foods: A number of studies have investigated the safety and toxicological aspects relating to the use of moringa leaves as a source of nutrients. The findings of an animal study by Villarruel-López *et al.* (2018) revealed no lethal dose and no significant differences in genotoxicity parameters at the tested doses. Another animal study by Moodley (2017) indicated that oral administration of MLP up to 2,000 mg/kg body weight showed no changes in clinical signs or gross pathology and that the LD50 was greater than 2,000 mg/kg. Owusu-Ansah *et al.* (2011) estimated hazard indices from the mineral composition of moringa leaves. Their findings indicated that there was no toxicity potential associated with the use of moringa leaves; however, the researchers recommended strict adherence to nutritionists' recommended dosage to avoid risk of overdosing of metallic minerals (Owusu-Ansah *et al.*, 2011). This recommendation is especially useful when considering the use of moringa leaves as an ingredient in fortifying foods of infants whose bodies are at crucial stages of development. A study by Olawoye *et al.* (2018) also revealed that there was a pharmacokinetic interaction between amodiaquine, a popular drug for the treatment of malaria, and MLP when given together or following a long period of ingestion of MLP (Olawoye *et al.*, 2018). This finding is particularly important, as it indicates that the presence of MLP may alter the amount of amodiaquine absorbed, thus resulting in either sub-therapeutic or toxic serum levels (Olawoye *et al.*, 2018). Given that MLP is being considered for use in infant and young child populations in low-resource settings where malaria is likely to be endemic, there is a high possibility of simultaneous administration of MLP with anti-malarials with little known ramifications, if infants

are fed with complementary foods fortified with MLP. There is a need for further investigation on the safety and toxicological aspects of the use of MLP, particularly as an ingredient to fortify foods of infants in low-resource settings.

Conclusion

There is no doubt that the addition of the nutrient-rich MLP to complementary foods in sufficient quantities will significantly improve their nutritional value. Despite the high nutrient content of MLP, it may not be successful in improving the nutritional status of infants in low-resource populations if the target consumers do not accept the new foods. Formulating complementary foods fortified with MLP to meet the nutritional needs of infant and young children in low-resource settings, however, is only one of many factors that could lead to improved infant and young child nutrition. Consumer acceptability of the fortified foods is key in the entire fortification process. To ensure success, nutrition interventions that involve the incorporation of indigenous foods like MLP to improve nutritional quality of complementary foods should necessarily consider the acceptability of the sensory attributes of the formulated blends in the target group. Well-designed acceptability trials, involving mother–infant pairs and lasting for extended periods, are urgently needed to help ascertain the minimum levels of incorporation of MLP that will be both acceptable and nutritionally beneficial to the target population. Safety and toxicological studies are also needed.

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