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Exploring food fortification potential of neglected legume and oil seed crops for improving food and nutrition security among smallholder farming communities: A systematic review

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ABSTRACT

A systematic review of literature on value-addition and food fortification of cereals using neglected legume and oil seed crops among smallholder farming communities was done. There is scanty and very limited empirical evidence on the use of legumes in food fortification of cereals at the household level. This is largely because of a neglect of local micronutrient provision initiatives at the household level, with much attention being done at policy and industrial scale food fortification levels. Besides, the current policies do not provide for the fortification of most food crops commonly grown in smallholder farming communities and there are very few initiatives that are in place to promote localised fortification options among rural communities. The paper consolidated existing knowledge on food fortification in general, value addition of small grains and neglected legume and oil seed crops. It explored fortification potential of sesame, cow pea and groundnuts and mapped existing gaps and missing links hampering the enhancement of food security and nutrition. This study recommends the promotion of groundnuts and sesame production, their value addition, and their use in the fortification of cereal food products to complement protein, Vitamins, Fe, K, Na, Mg, Zn, and Ca provision. This will significantly contribute to the alleviation of malnutrition among rural communities particularly in developing countries where agriculture is the mainstay of economies.

1. Introduction

Micronutrient deficiencies afflict more than two billion individuals, or one in three people globally [1]. FAO also estimates that one in nine people worldwide, resulting in a total of 795 million, are under-nourished and of these 780 million (about 98%) are in developing countries [2]. As such, food and nutrition security has become one of the most important contemporary debates topping the international political agenda for most governments around the world [2]. The World Bank [3] also estimates that 78% of the world's population is extremely poor and survive on incomes of less than the equivalent of USD 1.25 per person per day and about 70% of these people live in rural areas where they primarily survive on rain-fed agriculture for food production. As a result, an estimated 25 to 36 million pre-school children are affected by subclinical and clinical vitamin A deficiency [6]. In the Eastern and Southern Africa region alone, about 10 million children show clinical signs of micronutrient malnutrition. This situation has been exacerbated by the outbreak of COVID-19 pandemic leaving more children and adults vulnerable to under nutrition and hunger. Despite being reduced from 33% in 1990–92 to 23% in 2014–2016, the percentage of undernourishment remains the highest among developing regions [4]. This indication calls for use of locally available as well as low cost food fortification initiatives that utilises neglected and underutilized legume and oil seed crops to complement on iron, vitamins, zinc, folic acid, and other essential micro nutrients. The food utilization aspect is a key pillar of food security as defined by the 1996 World Food Summit report which

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states that food security "exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life" [5].

In most smallholder farming communities within semi-arid regions, micronutrient malnutrition is exacerbated by mono-cropping of staple native cereals (sorghum, pearl millet and finger millet) which are drought tolerant. In these marginal areas, a larger percentage of the population is malnourished because of poor health diets that are deficient of essential nutrients such as vitamins, folic acid, iron, and zinc. Food produced and consumed in these regions does not provide balanced diets to address the nutritional needs of the population particularly for vulnerable groups such as women, children, and the youth. Agriculture is the primary source of income, food and nutrition security for more than 70% of the sub-Saharan African population [7]. It is against this background that low cost food fortification has been regarded as one of the strategies that can be used to address the problem of micronutrient malnutrition among rural communities. FAO [8] defines food fortification as the addition of one or more essential nutrients to food, whether or not it is normally contained in the food, to prevent or correct a demonstrated deficiency of one or more nutrients in the population or specific population groups. Currently, the most commonly implemented food based strategies to combat micronutrient deficiencies are conventional industrial food fortification, bio fortification, and dietary diversification. Food-based strategies such as bio fortification, dietary diversification, and food-to-food fortification that encourage the utilization of local resources are increasingly being recognized as sustainable particularly among rural communities since they promote self-reliance and create market opportunities for locally produced foods [43]. Darton-Hill & Nalubola [9] argued that whilst there has been an enormous increase in fortification programs over the last couple of decades in developing countries, most of these programs have not been successful in reducing deficiencies of Fe, Zn, and Folic acid at a low cost particularly in smallholder farming communities. This is because, in most of these smallholder farming areas, there have been pronounced marginalization or neglect of locally available oil seed crops such as sesame (*Sesamum indicum*) and legumes which are rich in essential micronutrients (see Table 4).

Marginalized or neglected or under-utilized crops have been defined as crops that have not been previously classified as major crops, in particular crops that have previously been under-researched, and currently occupy low levels of utilization and are predominantly confined to smallholder and communal farming areas [40]. Of particular interest in this review, are small grains (sorghum and pearl millet) as well as oil seeds (sesame seed) and legumes that include cow pea and groundnuts. Historically, these crops have played an important role in ensuring community and household food and nutrition security through providing alternative healthy diets in instances where staple food crops fail or during period in-between subsequent harvests [41]. The renewed promotion of these crops, to reinstate them as alternative complementary food sources in agriculture will depend, to a large extent, on availability of information describing their agronomy, post-harvest management, and more importantly food processing options at the household level to combat undernutrition among vulnerable rural communities [42]. The primary reasons for focussing on these crops are that: they are easy to grow since seed can be locally sourced and they have limited inorganic fertilizer and other input requirements. The crops are popularly grown as intercrops and in the case of legumes, they are usually allocated infertile small plots under the management and control of women and the youths hence they do not require large pieces of arable land with high fertility. With the changing climatic conditions and weather variability, these small grains and legumes tolerate extreme weather events such as droughts hence they can be grown in marginal areas such as semi-arid regions.

Sesame seed, cow pea and groundnuts have potential as vehicles for fortifying cereal-based food products although much emphasis regarding food fortification has been channeled towards high-value industrial fortification of products such as sugar, margarine, wheat flour, rice, oils, salt and mealie-meal [10]. There is also a pronounced paucity of literature and empirical evidence regarding the value addition of sorghum, pearl millet, and neglected legumes such as sesame among smallholder farmers. Most of the small grains have been primarily consumed as standalone starchy diets with limited essential micronutrient content resulting in undernutrition especially among vulnerable groups such as women, children, and those with chronic illnesses in rural communities.

To date several regional policy frameworks by the African Union such as the broad Agenda 2063, have developed a shared vision on alleviating malnutrition through a shared strategic framework for inclusive growth and sustainable development. The Comprehensive Africa Agriculture Development Programme (CAADP), a Maputo declaration on agriculture and food security in Africa makes it mandatory for African Union member states to allocate at least 10% of national budgetary resources to agriculture and rural development policy implementation to support initiatives such as the food fortification and value addition. Similarly, in 2014, the SADC also developed a Regional Agricultural Policy (RAP) and the SADC Regional CAADP Compact to address the challenges of low productivity, undernourishment, and climate change with the overall objective to promote sustainable agricultural growth and socio-economic development. All these policy initiatives contribute to the attainment of global sustainable development goals (SDGs) of ending poverty in all its forms everywhere (SDG 1) and to end hunger, achieve food security and improved nutrition, and promote sustainable agriculture (SDG 2). However, these policies have focussed more on the macro-level (policy) with very limited options and focus on the micro-level (household). Also, most of the products earmarked for fortification (wheat flour, margarine, rice, and oils) are not easily accessible at a low cost for consumption by the majority of the rural populace.

This paper, therefore, makes a review of existing empirical evidence regarding efforts made in using low cost neglected legume and oil seed crops like sesame, cow pea and ground nuts as food fortification vehicles to provide micronutrients to cereal-based diets. It also seeks to explore options for processing of native cereals (sorghum and pearl millet), neglected oil seed (sesame) and legumes (cow pea and groundnuts) to provide more nutritious foods at a household level among smallholder farming communities. The objective is to generate knowledge gaps that can be pursued for further research to address the micronutrient malnutrition among smallholder farming communities in sub-Saharan Africa. Another objective is to explore the implementation of food fortification strategies that make use of neglected oil seeds and legume crops for value-added markets in smallholder farming communities of sub-Saharan Africa. The main questions under study include: To what extent have neglected legume and oil seed crops been used in fortification of cereals and what available value addition options are existing for native cereals and marginalized legume and oil seed crops? What nutrition potential do small grains (pearl millet and sorghum) and oil seeds such as sesame have in complementing essential macro and micronutrients in food products? To address these questions, the study used a systematic review of recent literature focussing on value addition and food fortification that has been done targeting cereal grain crops such as maize, sorghum, pearl millet, and other related food crops. Published journals, books, and conference proceedings were used to provide information covered in this review paper.

2. Methods and procedures

This study used a systematic review which involved the review of almost all published scientific articles, books, grey literature and conference proceedings that focus on value addition and food fortification of cereals, legumes and oil seed crops. It summarised empirical evidence based on the following criteria *viz*: (i) studies that have focused on food fortification in general (ii) literature that have investigated various value addition or processing of small grains and legumes into various food products and their use and (iii) studies that identified various food fortification vehicles and the associated micronutrients complemented. The summary of the method used is depicted in a schematic presentation in Fig. 1. This approach was used because a lot has been published on food fortification but there is uncertainty regarding the use of locally available legumes and oil seed crops as food fortification vehicles and also there is a need to ultimately establish a research agenda for future studies with regards to this subject area.

For the main systematic review sections of the paper, we searched English databases that include Scopus, Web of Science, PubMed and Google Scholar. Since this study is interdisciplinary, involving agriculture production, food security, food processing and nutrition, the literature on these topics were drawn using the following key word searches:

"Food fortification" AND "Value addition" AND "nutrition"

"Cereals" AND "legume crops" AND "Oil seed crops"

"Small grains" AND "Neglected crops" AND "Smallholder farming"

"Sesame" AND "Sorghum" AND "Millet" AND "Groundnuts"

The chronological procedure that was used to conduct the systematic review is depicted in Fig. 1.

3. Results and discussion

3.1. Significance of small grains in food security and nutrition in sub-Saharan Africa (SSA)

According to Rohrbach [11], sorghum and pearl millet are Southern African Development Community's (SADC) second and third most important cereal grains in terms of production and area grown respectively. Worldwide, cereals are primarily consumed in large quantities and at greater frequency by a vast majority of the population [12]. Sorghum and pearl millet are mainly grown to improve food security and nutrition of households and more than 90% of the SSA region's production is consumed as food in areas where they are produced. Cereals comprise the major segment of agricultural production of most countries and form the cheapest source food energy and constitute a high percentage of the calorie intake of human beings, particularly in developing countries such as Zimbabwe. Of all the cereals, maize is the dominant and widely grown. The most common consumption option for sorghum and millet in Zimbabwe is 'sadza' which is made from the flour of these cereals. However, poor post-harvest processing methods have contributed to contamination of the flour especially with soil which makes the mealie meal flour from these cereals less preferred than that of maize.

Consumption patterns of cereals for most smallholder farmers are characterised by starchy diets that do not provide all the required essential nutrients for a healthy diet. This is largely because of the limited food processing skills and technology among rural households. There is need for fortification of starchy cereal grain foods using cheap and locally available food crops such as sesame and groundnuts to enhance the availability of essential micronutrients such as iron, zinc, potassium, and magnesium. There is generally a lack of dietary diversification that include consumption of essential micronutrients, protein and nutritious vegetables among smallholder farmers partially due to limited value addition options for both cereal and legume crops. In Zimbabwe, the utilization of cereal crops ranges from direct food products to a few improved food products that are mainly consumed at the household level. Sorghum grain can be used as a substitute for maize and wheat meals.

According to a study by Orr et al. [15], sorghum and millet consumption have remained constant over the years as a proportion of total grain consumption as food. Sorghum accounts for about 7% of the region's grain calories. In sub-Saharan Africa, pearl millet consumption accounts for about 3.0% of the region's calories. However, demand for millets for direct consumption has been declining due to changes in food habits and inconvenience attached to food preparation as compared to fine cereals [16]. Furthermore, lack of processing technologies and also the disincentives due to non-existent and inconsistent government policies towards small grains have largely contributed to the limited production and utilization of small grains. The consumption of small grains food items has also been traditionally restricted mainly to growing areas where they are treated as major staple foods for most smallholder farmers. In Zimbabwe, the main sorghum variety grown is Kafir (*Sorghum bicolor kaffrorum*) and is mainly used as a grain crop. Sorghum grain is eaten after boiling the flour to produce foods such as *sadza*, porridge in

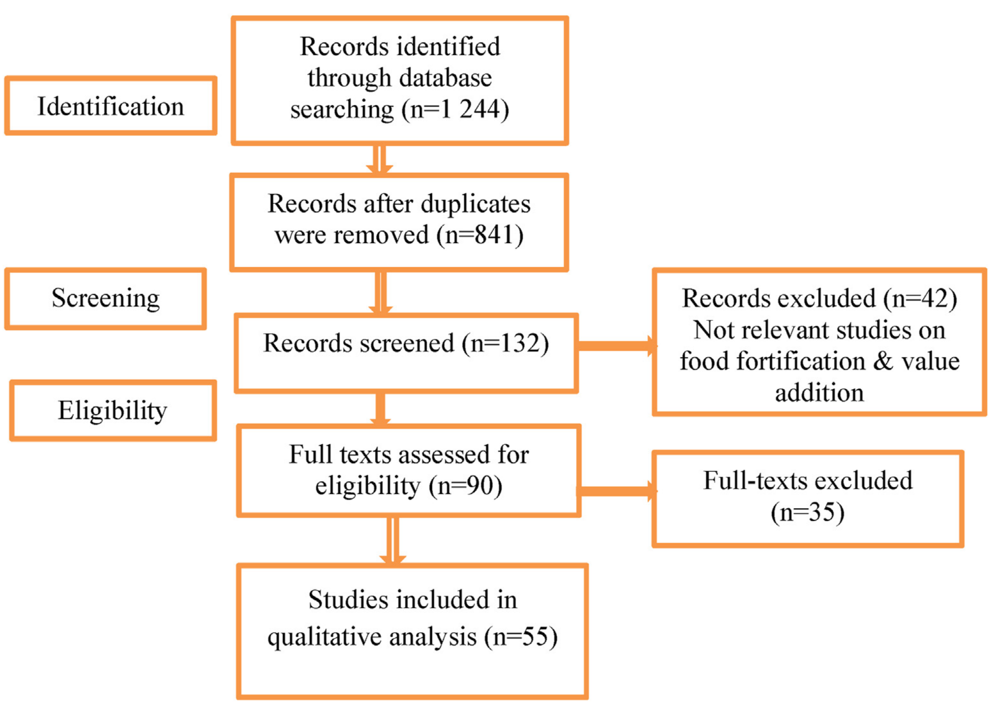

Fig. 1. Flow chart of the systematic review and qualitative synthesis.

Zimbabwe, *ugali, Uji* in East and Western Africa. In Ethiopia, *injera* is the most common food from fermented sorghum dough.

3.2. Value addition and use of small grains among smallholder farmers

Small grains are still chronically underutilized, to the detriment of the wellbeing of the people in developing countries. The major reason for their underutilization is that they are under-researched [18]. Cereal grains are extremely versatile foodstuffs and can be processed into a wide range of traditional food and beverage products. According to Taylor & Emmambux [20], there are three main categories of products that can be produced from cereal grains and these are i) whole-grain food products which include; rice type, popped and puffed grains, for example, popped grain, samp ii) food from meal and flour such as fermented flatbreads, unfermented flatbreads, couscous dumplings, and doughs, stiff porridges, thin porridges and gruels as well as iii) beverages; non-alcoholic beverages (*mahewu* in Zimbabwe and *Oshikundu* in Namibia), alcoholic (opaque beers), and spirits. The most common products are porridges both thick and thin especially in Zimbabwe. Large scale commercial production of cereal grains is still rather limited with the production of opaque beer from sorghum being an exception. Maize is steadily replacing these cereal grains in this industry mainly because of the ready availability of commercial maize grain on the market [20]. Studies by Taylor & Emmambux [20] and Rohrbach &Mutiro [18] have proved that new products are being developed from these traditional cereals. These foods have been developed in recent years targeting the rapidly growing middle-class urban population.

3.2.1. Sorghum

Value addition of sorghum grain can be done by processing it into opaque beer and this is common among rural communities in Zimbabwe and South Africa. Sorghum can be processed into flour and may substitute wheat. Sorghum flour is used in the bakery industry and households to produce different products that include cakes, bread, biscuits flakes, and other products. The value addition of sorghum also involves popping by exposing the grains to high temperature for a short time. Different methods of popping have been used and include hot air popping, gun puffing, popping in hot oil, and microwave popping. Furthermore, popping sorghum is known to improve shelf life and nutritional quality of the grain. Popped sorghum can further be used to make snack foods [13]. Rohrbach & Mutiro [18] argue that while 90% of sorghum and millet are consumed directly as food by humans, the stock feed industry also plays a significant role in the utilization of a significant proportion of these. There are several instant sorghum-based porridge products. The sorghum flour is pre-cooked to make porridge which can is only necessary to stir the flour into boiling water. In east Africa there are many protein and micronutrient-enriched finger millet and sorghum-based flours on the market. What characterizes these products is that they are based on traditional foods, normally porridges, and often they are acidified with fruit acid to mimic the natural lactic acid fermentation flavor. Such products are available in most urban markets which are far from the reach of the rural poor and are rarely found in most smallholder farmers set up despite them being the ones that dominate the production of these cereals. Research indicates that South Africa has the largest stockfeed industry consuming about 4 million tonnes of grain per year with most of it being maize, however, sorghum and millet account for less than 4% of the grain allocated to stock feed production.

3.2.2. Pearl millet

Pearl millet is mainly grown as a staple cereal crop mostly in semi-arid regions, however, its utilization has remained very low possibly due to several anti-nutritional factors the, for example, phytates and polyphenols that are found in the grain. Processing of pearl millet adds value and increases its utilization. The first process is de-hulling or decortication by removing outer layers of grain to reduce fiber, ash, and oil, increasing nutritional quality. The process of de-hulling is followed by milling which produces flour that is used to make porridge. However, the shelf life of that flour is very short due to the presence of high oil content. This limitation can be reduced by moist heating and drying the grains followed by decortication. Blanching has also been reported to increase the shelf of millet flour without changing the nutrient content of the flour [13]. Despite all the available value addition options, Dera [14], argues that very little knowledge exists among smallholder farmers on value addition mainly due to lack of knowledge on value addition coupled with non-availability of equipment necessary to replace the labor-intensive work that is required in the processing of the seeds.

The value addition of pearl millet is very important to increase its production and utilization [13]. Similar to sorghum, pearl millet is grown for its fodder or grain purposes. However, in most developing countries, pearl millet is mainly grown as a staple food crop. The flour from milling pearl millet is used to make various bakery products such as bread, biscuits, and cakes. However, the flour of pearl millet is not good for bakery due to the absence of gluten and it makes dough of poor consistency. Mixing with wheat flour helps improve the quality of the dough. Grain processing that involves de-hulling and milling results in a by-product called bran that can be used to make edible oil and de-oiled bran can be a source of dietary fiber. Dietary fiber can be used to make flakes for obese people. The third process of pearl millet is malting and is done by allowing limited germination of the grain under moist controlled environments. Malted pearl millet is normally used in the brewery industry to make beer.

A knowledge gap exists in the context of assessing how post-harvest techniques and storage methods among smallholder farming communities influence the nutritional quality of food products from sorghum and pearl millet. Another research gap lies in the failure to produce more diversified food products from cereals due to limited value addition options available particularly at community and household levels in semi-arid regions. In Zimbabwe, flour from sorghum and millet is predominantly utilized as food *(sadza)*. Research by Goworindo [17]; Dera [14] indicate that there is great potential in utilizing various value addition options for most agricultural products including the neglected cereal grains among smallholder farmers so that the SDG goal of eradicating hunger and enhance food and nutrition security can be achieved. Dera [14] even argues that there are relatively few products on the market from small grains (sorghum and pearl millet) other than flour, which is an opportunity this study would like to focus on and try to develop new products that will increase consumption of these cereals.

3.3. Mineral composition of small grains commonly consumed among smallholder farming communities

Cereals constitute important nutrients however, the refining process degrades their quality and bioavailability**.** These grains constitute the majority of daily food sustenance especially among vulnerable people in rural communities. This makes small grains strategic crops for use as during food fortification initiatives since they do not result in complete change of household diets. According to Omoniyi & Abdulrahman [19], the proximate composition of most cereal crops is similar but the individual crops have peculiar compositions that make them different from each other. Some contain large proportions of protein for example millet and others practically none. A characteristic of all cereals, however, is that they contain a large amount of carbohydrates and a small amount of water [19]. Omoniyi and Abdulrahman [19], report that available carbohydrates are found to be 75.86% and to 72.99% in sorghum and millet respectively. The highest protein content was found in wheat (12.39%), while maize contained only 8.58%. The ash content was 0.56% and 1.67% for rice and millet respectively. Fat and fiber were found to range between 2.50 to 3.94% and 1.09–3.19% respectively. An appreciable amount of sodium was found to be the same in wheat and millet (383.33 mg/100 g) and potassium was in the range of 183.33–416.67 mg/100 g. Zinc content ranged from 9.27 to 11.73 mg/100 g and Iron content was between 48.73 and 67.22 mg/100 g (see Table 2). The results were compared with certified standard reference material (SRM) and revealed that consumption of the cereals at a suitable limit of quantification may satisfy the recommended daily dietary allowances of minerals and a good source of energy. However, the results also indicate that there is limited availability of essential micronutrients in these cereals hence there is a need for fortification of cereal based foods using other crops such as sesame and groundnuts. Table 1 and Table 2 indicate a summary of the proximate analysis done to some cereal samples.

All the samples analyzed showed that they were rich sources of micronutrients (Table 3) since the results were generally within the WHO/FAO recommended levels.

3.4. Productivity of legume crops among smallholder farmers

Legumes, often referred to as the "poor man's meat", play an important role in the diet of millions of people in the developing countries. Legumes are important sources of protein, calcium, and phosphorus hence they form part of the diet of many vulnerable groups of people [21]. In most developing countries legumes are grown primarily as secondary crops intercropped and sometimes used as rotational crops with cereals because of their role in biological nitrogen fixation. However, Nedumaran et al. [21] argues that the yield and production of these legume crops over the past decades has been stagnant in most developing countries. Further to this, some of the legume crops such as sesame and cowpea have been forgotten and neglected yet they are potentially cheap and readily available vehicles of food fortification in smallholder farming communities. This is well buttressed by Abate et al. [22] who also argue that agricultural research and development has focused mainly on yield improvement and productivity of cereal grains only and lowering crop losses to achieve food security. The diverse role played by legumes in ensuring food and nutrition security as well as their role in most farming systems means that improved research targeting legume crops would have significant impact on nutrition security as well as sustainable cropping systems.

Legumes lag behind cereals in terms of production area expansion as well as productivity. According to Abate et al. [22], the area allocated for planting legume crops stands at 27 million hectares in Sub Saharan Africa (SSA) and the estimated annual production stands at approximately 19 million metric tonnes (MT). The average yield of these legumes is less that 1 MT per ha which is far below the expected global yield. The major reason for this yield gap is that legumes are considered secondary crops to cereals in terms of consumer preferences and research activities have thus focussed more on cereals. This review intends to provide the potential of legumes and oil seed crops use in food fortification and ultimately promote the production of these crops among rural communities.

Table 1
Traditional foods made from Sorghum.

Type of food	Common names	Countries
Unfermented bread	Roti, rotii	India
Fermented bread	Kisra, dose, dosai, galletes, injera	Africa, India
Thick porridge	Ugali, tuwo, saino, dalaki, aceda, atap, bogobe, ting, tutu kalo, karo, kwon, nshimba, nuchu, to, tuo, zaafi, asidah, mato, sadza, sangati	Africa, India
Thin porridge	Uji, ambali, edi, eko, kamo, nasha, bwa kal, obushera, Ogi, oko, akamu, kafa, koko, akasa	Africa, India Nigeria, Ghana
Sweet/sour opaque beers	Burukutu, dolo, pito, talla	West Africa
Sour opaque beers	Marisa, busaa, merissa, urwaga, mwenge, munkoyo, utshwala, utywala, ikigage	Sudan, southern Africa
Non-alcoholic beverages	Mehewu, amaheu, marewa, magou, feting, abrey, huswa	Africa

The high demand for cereals has pushed the production of legumes to marginal areas that are characterised by low rainfall and poor soils, a characteristic of most parts of Zimbabwe's smallholder and communal farming areas. Another school of thought for the lag in legume production is the fluctuations in the price of the legumes which usually emanate from high variability in yield and the competition they suffer from cereals [22]. Production of tropical legumes, particularly in Africa, is characterised and constrained by smallholder farmers whose average household head age is 48 years; average schooling is less than 4 years; average area of land under grain legumes is less than 0.2 ha, and arable landholdings are largely fragmented due to the insecure land tenure systems [22]. Hence tropical legumes are largely produced by vulnerable and marginalized groups with limited skills and technology to produce and process them into nutritious food products.

3.4.1. Cowpea

Cowpeas (*Virginia unguiculata* L.) production in Sub Saharan Africa accounts for 84% of the total area under production [23]. The average yield in most SSA countries is 450 kg per ha, the lowest for all tropical grain legumes. In Zimbabwe, cowpeas are grown in most parts of the country from an agroecological region I to V, but mostly within the smallholder farming community dominated by natural farming regions IV and V. These regions are mostly marginalized areas where both rainfall and soil fertility are poor. Cowpeas constitute a major part of the diet among most smallholder farmers. However, yields for the cowpea are significantly low with an average of 0.45 t/ha [23].

3.4.2. Groundnuts

Groundnut (*Arachis hypogea* L.) is one of the widely grown major legume crops. An estimated 86.6 million people grow groundnuts in the SSA region with an average yield of 1000 kg per ha [24]. In Zimbabwe, yields vary from about 400 kg to several tonnes per hectare depending on the production system and production area [25]. Production ranges from highly commercial to more traditional smallholder production. However, the crop is an important part of the diets of most smallholder farmers who reside in natural regions IV and V by providing an important source of protein and other various products. Production of the crop is therefore dominant in these areas.

3.4.3. Sesame

Amongst the oil seed crops, sesame (*Sesamum indicum* L.) is the most preferred food crop because of its multipurpose function. In Africa, the production of sesame stands at 40% of the world's production with countries like Nigeria, Ethiopia, and Sudan being ranked highest for producing the crop [26]. Sesame is mainly produced by smallholder farmers primarily relying on relatively poor soils with limited inputs hence resulting in low yields of about 300 kg/ha [26]. In Zimbabwe, sesame is one of the most neglected crops and as such it is grown in natural regions IV and V, mostly at the household level for consumption and also as a cash crop [27]. Sesame yields usually take an average of 300–500 kg/ha depending on the management of the crop. However, due to the limited production as well as research attention, there is scanty sesame agronomic information in most developing countries, Zimbabwe included. Reports from the Zimbabwe Crop and livestock Assessment of 2017 indicate that sesame is not even classified as one of the oilseed crops, which points directly to the argument that the crop is neglected, hence it is only grown and utilized in smallholder and communal farming systems. Very limited production records exist for the crop in recent years although a few programs like the Livelihoods and Food Security Program funded by the USAID have started commercialization of sesame among smallholder farmers in Gokwe, Mount Darwin, and Guruve districts of Zimbabwe. These efforts need to be augmented by improving and upgrading the sesame value chain through improved processing methods that unlock the nutritive value of the crop hence the need for this review paper.

Table 2
Proximate composition (%) of samples of some cereals available in Zimbabwe.

Cereals	Moisture	Protein	Fibre	Ash	Fat	Carbohydrate
Sorghum	8.04	10.13	1.86	1.41	2.70	75.86
Millet	8.56	11.03	3.19	1.67	2.56	72.99
Maize	9.19	8.58	2.83	1.16	2.85	75.39
Rice	8.31	10.49	1.09	0.56	3.94	75.61
[a]RV	<5.00	7–15.00	1.00–7.00	<5.00	<3.00	≥64.00

Values reported were an average of duplicate analysis.
[a] RV (*Recommended values).
Source: Abdulrahman and Omonyi [19].

Table 3
Mineral composition (mg/100 g) of samples of some cereals available in Zimbabwe markets.

Cereals	Na	K	Ca	Mg	Fe	Zn
Sorghum	350	400.00	30.82	97.55	48.73	10.05
Millet	383.3	366.67	9.00	98.18	52.87	10.95
Maize	333.3	300.00	12.95	77.62	58.35	9.45
Rice	126.67	183.3	3.35	23.67	59.33	9.27
RV	296.00	516.00	60.00	76.00	≥16.00	≥3.20

Values reported were an average of duplicate analysis.
*RV (*Recommended values).
Source: Abdulrahman and Omonyi [19].

3.5. *Utilization of legumes crops among smallholder farmers*

In most rural communities, the processing and utilization of grain legumes have a long history that is intimately linked to women and their traditional livelihood tasks [28]. There is a great advantage in promoting grain legume and oil seed crops for improved household nutrition in semi- and arid tropics where women have greater influence over household food choices, child nutrition, and ultimately health. Grain legumes such as groundnuts and cowpeas as well as oil seed like sesame, are essential food sources as well as income in tropical and sub-tropical regions. Legumes therefore, play a vital role as sources of protein, calcium, iron, phosphorus, and minerals. Nedumaran et al. [22] ascertain the point that legumes are multipurpose crops and are consumed either directly as food or in various processed forms or as feed-in many farming systems. Chibarabada et al. [28] also asserts the fact that grain legumes contribute significantly to diets of rural households if consumed as complements of starchy diets. One of the major concerns of the rural population diets is protein-energy malnutrition of which grain legumes play a pivotal role in complementing the dominantly starchy diets.

3.6. *Uses of selected legume and oil seed crops for food consumption*

3.6.1. *Cowpea*

Cowpea is an important legume in Sub-Saharan Africa compared to other regions, where consumption has grown at a rate of 3.2% per annum between 1980 and 2009. The average level of consumption is 4.5 kg/person/year in Sub-Saharan Africa Nedumaran et al. [22]. In Africa, the crop is grown for its edible seed and foliage. Fresh green pods are eaten as snap beans while the tender leaves are served as a vegetable. Dry mature seeds can be boiled and canned to preserve them. However, dried grain can be milled into flour or meal which has potential for branding and unbranded packets [13]. Cowpea flour is more refined than the meal. The meal can be used to produce cowpea fritters which can be served as a snack or breakfast. Other products such as cakes, rock buns, doughnuts, biscuits, fried cowpea paste, and thick cowpea porridge can all be produced from cowpea seed [22]. Other innovative technologies besides milling such as decorticating, fermentation, and extrusion have been tried in Ghana to produce weaning mixes, blending, and new fortification formulas. The foliage can also be used to feed livestock. In most smallholder farming systems, stover from harvested cowpea fields is stocked for feeding animals especially during the dry season when the quality of graze deteriorates drastically.

3.6.2. *Groundnuts*

According to Singh & Diwakar [29] groundnuts are consumed as freshly harvested seed or dry kernels. Freshly harvested pods can be boiled or roasted with or without salt and served as a snack. Post-harvest processing techniques such as shelling produce nutritive groundnut haulm which is used to feed livestock while the hulls can be added to manure. Shelled groundnuts can be roasted or boiled with or without salt and served as a snack [13,28]. The most popular product from groundnuts is peanut butter especially in most Western and Southern African countries. The butter is used as a spread on bread and in the food industry to make candy, cookies, and sandwiches [28]. Another prominent product derived from groundnuts is oil which is produced through the oil extraction process. Oil is used in cooking and can be processed into margarine and soap. Groundnut oil can also produce candles, cosmetics, and leather dressing oil although on a small scale. Oil extraction results of groundnut results in the production of groundnut cake which is used in the bakery industry to make biscuits, bread, and cookies. Singh & Diwakar [29] reiterate the fact that fermenting the cake improves the digestibility of products and this can aid the production of nutritious and tasty products. Groundnuts can also be used to produce milk. Groundnut milk is produced when the nuts are soaked into 1% sodium bicarbonate for 16–18 h. When the milk is fermented it can be used to make yogurt and can substitute up to 20% in ice cream production [29].

3.6.3. *Sesame*

Sesame is one of the oldest, traditional oilseed crop grown for its valued high-quality seed oil. The crop is grown for its flavorsome, edible seed and high-quality oil. Sesame seed contains high oil content (46%–50%) with 83%–90% unsaturated fatty acids, 20% proteins, and various minor nutrients such as vitamins and minerals, a large number of

Table 4
Proximate composition of the commonly consumed legumes (g per 100 g).

Components	Chickpea	Pea	Lentil	Broad bean	Bean	Soya bean	Peanut	Sesame
Proteins	23.6	21.9	20.6	26.6	21.3	36.9	24.8	33.54
Carbohydrates	62.3	52.5	56.4	35.4	47.8	6.1	19.0	4.71
Fibre	3.8	10.4	6.83	31.3	18.4	20.9	3.1	5.65
Lipids	6.4	2.3	2.15	1.8	1.6	18.1	49.7	40.37
Ashes	3.7	3.0	2.8	4.1	4.0	4.7	2.0	4.03

(Source: Sanchez-Chino et al. [35]).

characteristic lignans such as sesamin, sesamol, sesamolin and tocopherols [30]. North and Central Africa are the predominant producers of the sesame with countries like Sudan and Ethiopia topping among many in the production of the crop. However, in Sub Saharan Africa, Zimbabwe, in particular, sesame is one of the neglected crops grown mainly at household level in natural regions IV and V but is receiving renewed attention because of its multi-purpose function. Sesame derives its high value from its many uses both in domestic and export markets. The crop is used as an additive in the confectionery industry on bread and buns. However, the prime product from sesame is sesame oil. Rich in vitamin E, the oil has medicinal and pharmaceutical value and is being used in the manufacture of many health care products [31]. The seed also has anti-oxidants lignans such as sesamolin and sesamin and used as active ingredients in antiseptics, bactericides, viricides, and disinfectants. After oil extraction, the remaining meal contains high amount of proteins and calcium which is an ingredient in the animal feed industry [30].

Available information shows that the most common product from sesame among smallholder farmers in Zimbabwe is sesame butter or *Tahini* as it famously called in the northern countries. The butter is prepared by roasting the seed and pounding the seed in a pistil and mortar and other products such as roasted seed are served as a snack with some salt. Very little to none is done in terms of oil extraction especially among smallholder farmers. Some of the major reasons include lack of knowledge on value addition for the crop and coupled with non-availability of machinery necessary for oil extraction [14]. Much of the sesame produced by smallholder farmers is sold to middlemen and companies despite the huge potential the crop has in terms of improving household food and nutrition security at the local level.

3.7. Selected legumes and oil seed crops and their role in food fortification

Food crops which include cowpeas (*Vigna unguiculata*), groundnuts (*Arachis hypogea*), and sesame (*Sesamum indicum*), represent an important component of agricultural food crops consumed in developing countries, especially in Sub-Saharan African countries. The important and diverse role played by legume and oil seed crops in the smallholder farming systems and diets of poor people makes them ideal crops for achieving developmental goals of reducing poverty and hunger, improving human health and nutrition, and enhancing ecosystem resilience. Considering the availability of these food legumes among smallholder farmers, there is potential in the use of these food legumes crops as food fortification vehicles of native cereals.

Groundnuts can be used as freshly harvested seeds or dry kernels. Freshly harvested pods may be boiled or roasted with or without salt and served as a snack. Post-harvest technologies in drying groundnut are very fundamental to the value addition of the crop. These technologies include adequate drying, cleaning, de-stoning, and grading of groundnuts. The processing of drying groundnuts begins with shelling and can be done by hand or machinery; this also adds value to the crop. Nutritive groundnut haulm from shelling can be used to feed livestock while the hulls can be used to make compost manure. Shelled groundnuts can also be boiled or roasted with or without salt and served as a snack [13]. The most popular value-added product from groundnuts is peanut butter. Peanut butter plays an important role in providing the much-needed plant protein in the diet.

Cowpea is grown for its edible seed and foliage. Fresh green pods are eaten as snap beans while the tender leaves are served as a vegetable. Dry mature seeds can be boiled and canned to preserve them. However, dried grain can be milled into flour or meal which has potential for branding and unbranded packets [13]. Other innovative technologies besides milling such as decorticating, fermentation, and extrusion have been tried in Ghana to produce weaning mixes, blending, and new fortification formulas.

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3.8. Proximate mineral composition of common legume and oil seed crops

Groundnuts are not only rich in proteins that are easily digestible and consequently, a higher biological value, but are also rich in B-complex vitamins according to Ref. [32]. It is an important item in several confectionery products, and in supplementary feeding programs such as in weaning food formulations in combination with cereals and pulses in many developing countries. The principal use of groundnut, however, is in the production of oil as well production of peanut butter among others [32] Proximate analysis of the crop has been done by several researchers and results show that legumes are rich sources of proteins (30.12 ± 1.94 g/100 g), fat (42.60 ± 1.81 g/100 g) as well as micronutrients such as calcium, potassium, iron, and zinc. Tables 4 and 5 summarises the proximate composition of groundnut as analyzed by Ref. [33].

The reliance on non-nutritive and starchy foods for the daily survival of many households that live below the poverty datum line justifies the need to provide vulnerable communities with information about the nutritive value of some underutilized crops readily available in their domain. Sesame seed is a tropical annual crop and one of the oldest cultivated plants in the world. It is a highly prized oil crop in most countries in the world. Proximate analysis of the crop as analyzed by Ref. [34] is summarised in Table 4.

The results in Table 4 show that sesame seed contains fat (40.37 g/100 g), crude protein (33.54 g/100 g), ash (4.04 g/100 g), moisture (11.70 g/100 g), fiber (5.65 g/100 g), carbohydrate (4.7 g/100 g). Relatively similar results were also obtained from a study by Atasie et al. [36] who showed that the proximate analysis of groundnut contains fat (42.6 g/100 g), crude protein (30.12 g/100 g), ash (2.51 g/100 g), moisture (1.57 g/100 g), fiber (2.70 g/100 g) and carbohydrate (79.01 g/100 g). Generally, legumes are rich in protein and fat while they are low in carbohydrates. These results in Table 4 reveal that sesame can be used as a good supplement of protein in cereal diets. Table 5 also depicts that sesame seed and groundnuts are potential food fortification vehicles for micronutrient provision in cereal-based diets. There are significantly high levels of sodium, potassium, zinc, and calcium (Table 5) in sesame seed relative to other commonly consumed legumes such as groundnuts and cowpea. This study therefore reveals that sesame and groundnuts can be promoted to enhance micronutrient provision in cereal diets in semi-arid regions in smallholder farming communities. Therefore, there is a need for further studies to explore the fortification potential of sesame and groundnuts in different diet formulation to combat undernutrition especially in rural communities where there is high vulnerability to food insecurity and nutrition challenges.

The predominant mineral in legumes is potassium. According to Ogungbenle & Onege [34], the levels of K, Na, Mg, and Ca in legumes were found high in the samples analyzed. The values obtained for the essential minerals in the samples are within range of satisfying the nutritional needs of the consumers according to FAO/WHO nutrient requirement guidelines. Groundnut and sesame are potential sources of both macro and micronutrient provision and studies by Ref. [34] suggest

Table 5
Proximate mineral analysis of sesame and groundnuts (mg/100 g).

Mineral	Sesame	Groundnuts
Sodium	87.21	42.00
Potassium	96.33	705.11
Calcium	61.37	2.28
Iron	7.29	6.97
Zinc	19.29	3.20

Source: Atasie et al. [36].

that sesame seed is not detrimental to human health because of its low levels of anti-nutrients; and also that it has potential for infant food fortification in food industries. Legumes are described with many important attributes including high nutritional value, long storage times, and relatively low cost in comparison to animal products. Legume and oil seed crops are therefore valuable sources of affordable protein particularly for rural small-holder communities that largely depend on cereal-based diets and face high risks of malnutrition [37]. Studies on food fortification must focus on different age groups with regards to their specific dietary requirements and determine how sesame can be used to meet their essential nutrients. Of particular interest will be the effect on infants, pregnant women, and weaned children who are highly vulnerable to micronutrient malnutrition in rural communities.

3.9. Food blends and fortification options for legumes and oil seeds among rural communities

The feasibility and suitability of cereals, oil seed and legumes in the development of blended meals for enhancing nutrition in human has been extensively reviewed [53,54]. As a result, many studies have reported success in improving macronutrient deficiency particularly among children. Value addition to agricultural products is the process of increasing the economic value and consumer appeal of an agricultural commodity [38]. Value addition involves producing a commodity for a special market, changing the form of the commodity before it is marketed, changing how a commodity is packaged and branded for the market, changing the way a commodity is marketed, or even adding a new enterprise to an existing one [17]. Food fortification is the practice of deliberately increasing the content of an essential micronutrient, i.e. vitamins and minerals (including trace elements) in a food, to improve the nutritional quality of the food supply and provide a public health benefit with minimal risk to the health of consumers [40]. Fortification of cereal grain foods has been regarded as an effective strategy that can be used to overcome nutrient deficiencies particularly among smallholder farmers in semi-arid regions. Micronutrient deficiencies, especially of vitamin A, iron, iodine, and zinc, have been widely reported to be prevalent in both developing as well as some developed countries. Food fortification is dependent on existing food production and distribution systems and requires little external support. This is crucial in addressing the challenges of micronutrient deficiencies at the household level.

There is very little to no information on the use of food legumes in value addition and fortification of native cereals with special focus on the smallholder production, processing, and marketing in Zimbabwe. Food legume and oil seed crops are grown traditionally for consumption in agro-ecological regions IV and V of Zimbabwe characterised by erratic rains and poor soils. However, there are few to no available options on the market of nutrient supplements that can be used by the general populace for food fortification especially in rural areas. This is primarily because households in these areas do not afford micronutrient supplements and industrial fortified food products. Moreover, there is limited technology and skills in developing local nutritious food products The potential benefits of fortifying native cereals using food legumes especially sesame, groundnuts, and cowpeas are unknown as this has not been explored before. According to statutory instrument 120 of the Government of Zimbabwe, the cereal fortification program in Zimbabwe is targeting edible vegetable oil, salt, sugar, maize meal and wheat flour as the main vehicles. Very little effort has been made to promote value addition and fortification of cereals which are the major food products consumed by smallholder farming households. Most smallholder communities are missing out on the potential benefits of value addition and fortification, as currently there are no deliberate efforts by the Government to fortify and improve the consumption of native cereals which are staples for most smallholder communities at the household level. Table 6 gives a summary of the various cereal and legume food blending studies that were undertaken in various countries and chronicles the results and scope of the studies (see Table 7).

Table 6 depicts the various cereal and legume food blends that were developed with the objective of meeting protein and amino acid requirements in humans. Porridge, flakes, biscuits and snacks were developed using cereals such as maize, sorghum and wheat as well as legumes (groundnuts, cowpea and sugar beans). Asma et al. [51] also used sesame seed blended with sorghum to produce weaning porridge resulting in improved protein and amino acids in the porridge. Whilst these efforts are commendable, there is need to explore the potential of these legume and oil seed crops for use as food-to-food fortification vehicles to address micronutrient malnutrition. The development of these food blends using locally available technologies and innovation methods have primarily centred on improving protein content and alleviation of Protein Energy Malnutrition (PEM) with very limited focus on micronutrient deficiency. In Kenya, food-to-food fortification strategy is gaining traction although there is a dearth in in-depth empirical evidence on the effectiveness of the strategy in increasing micronutrient bioavailability, status as well as growth, development, and health [43]. This is a major research gap that require extensive exploration to contribute to the alleviation of micronutrient deficiency at the household level.

3.10. Potential challenges to food fortification and value addition of legumes and oil seeds crops

Fortification of cereals with neglected legume and oil seed crops also has a number of drawbacks. Most of these crops have been under researched and hence very little empirical evidence regarding their agronomic and postharvest practices does not exist. This is particularly evident with regards to sesame oil seed. There is limited productivity of

Table 6
Cereal and legume food blends formulated to improve protein and amino acid content of food in different countries.

Cereal	Legume/oil seed	Food product	Protein/amino acid changes	Country	References
Wheat	Sesame	Flour/porridge	Significant protein increase (18.42–20.83%. Lysine increase (0.21–0.49%)	Sudan	Fathelrahman et al. [44]
Wheat	African yam bean Cocoyam	Cookies	Significant protein increase (10.44–14.73%)	Nigeria	Igbabul et al. [45]
Sorghum	Cocoyam Pigeon pea	Cookies	Significant increase in protein BV (73.86–95.46%)	Nigeria	Okpala & Okoli [46]
Sorghum	Sugar beans	Porridge	Significant increase in protein (13.33%)	Botswana	Jackson et al. [47]
Maize	Cow pea	Porridge	Significant increase in protein (2.19–3.5%)	Nigeria	Madukwe et al. [48]
Sorghum	Marama bean	Porridge	Significant protein increase (61–96%)	South Africa	Kayitesi et al. [49]
Maize	Groundnut	Porridge	Significant protein increase	Canada	Ejigui et al. [50]
Sorghum	Cow pea Pigeon pea Groundnut Sesame seed	Flakes/weaning porridge	Significant protein increase (16.6–19.3%)	Sudan	Asma et al. [51]
Maize Sorghum	Soyabean Chickpea	Snack	Significant protein increase	Egypt	Ismail et al. [52]

Source: Adapted from Makumba et al. [55].

Table 7
Summary of literature on food-based strategies in value addition and fortification.

Author and year	Title	Main findings	Comments
Darnton-Hill &Nalubola [9].	Fortification strategies to meet micronutrient needs: Success & Failures	The authors emphasize the success in using food vehicles such as sugar, salt, margarine in food fortification	Authors found that fortification has been successful but to a limited extend especially for Fe, Zn Folic acid hence there is a need to explore other food vehicles for enhancing the availability of Zn and Fe.
Tontisirin et al. [10].	Food-based strategies to meet the challenges of micronutrient malnutrition in the developing world	Increasing dietary diversification and integrated farming reduces the challenges of micronutrient intake	This paper proposes integrated agriculture production of a variety of food crops to enhance the right food combinations that improve dietary diversity. It also advocates for value addition (processing) and food preparation techniques which is in line with the fortification strategy
Chandiposha et al. [13]	Utilization of common grain crops in Zimbabwe	Grain crops like maize, soybeans, wheat, sorghum, and many others contribute immensely to the food security of Zimbabwe. Value addition results in various products from each grain crop and this may increase utilization and profitability. Knowledge on utilization and value addition of grain crops can be viewed as strong strategies in promoting its production	The authors note the importance of small grain crops in contributing to food security. However, value addition is viewed as important in terms of increasing utilization as well as production.
Choudhury et al. [38]	Value addition to bamboo shoots: A review	There exists great opportunity especially in an organized sector to take up plantation, harvesting, processing and marketing of bamboo and bamboo shoots- based food products	The research relating to bamboo and bamboo-based products are lacking in the international scenario. This is similar to small grains research on value addition. Research in value addition of small grains has not taken international scenario despite the crops being an important food source for many developing countries
Liu et al. [39]	Food fortification in India: A literature review	Food fortification research in India suggests it effectively improves biological markers of nutritional status, particularly when fortifying with multiple micronutrients or iron.	Food legumes have a potential for multiple micronutrient fortification if they are used in fortifying native cereals. The potential benefits realized by multiple micronutrient fortification can as well be realized by smallholder farmers.
Verma & Patel [12]	Value-added products from Nutri-cereals: Finger millet (Eleusine coracana)	Food is consumed in combinations. The synergy between foods with others is vital not for taste and delight of eating but also their high nutritional quality and health benefits.	There is a need to consider synergies between small grains and legume foods and this can only be achieved through value addition and fortification. The potential benefit derived from the synergy is crucial for fighting micronutrient malnutrition.
Bhat et al. [30]	Value addition in sesame: A perspective on bioactive components for enhancing utility and profitability. *Pharmacognosy Reviews*	Sesame has some beneficial bioactive components which are of health benefits to consumers	There is great potential in the utilization of sesame as an alternative protein and oil source for smallholder farmers.
Dera [14]	Sorghum and millet processed products available in retail supermarkets.	The main products in the retail market are direct flours from sorghum and millet. There is very little to none knowledge about the value addition of these cereal grain among smallholder farmers. Non-availability of machinery necessary to replace the hard work that is required in the processing of the seeds is another critical issue hindering value addition among smallholder farmers.	The range of products in the retail market is limited. There is scope to improve a variety of products available on the market to improve utilization. There is a need to train smallholder farmers on value addition and fortification for them to benefit from the crops they grow There is a need to address the crucial issue of hard labor needed in the processing of these small grains for increased production

neglected crops and also their value addition information is not well documented. Some of the crops require sophisticated machinery for processing for example groundnuts turn into a paste which makes it very difficult to formulate blends and it limits shelf life of the fortified food product. These neglected legume and oil seed crops have not been properly profiled in terms of nutrient content with reference to specific location. This makes it practically difficult to formulate rations that complement each other in terms of micro nutrient content hence jeopardising efforts aimed at promoting localised value addition and food fortification. Legumes and oil seeds also contain compounds that inhibit digestibility and bioavailability of protein and minerals. These inhibitors include phytates, lectins, tannins, saponins, amylase and proteases. Several non-heat treatment methods have been used and these include: imbibition, germination, dehulling and fermentation whilst non-heat treatment include cooking at atmospheric pressure and autoclaving. Whilst these methods have been used in the processing of legumes and oil seeds, not much of the methods have been evaluated in terms of micronutrient digestibility and bioavailability in circumstances where they are used as food fortificants.

4. Conclusion

Small grains which mainly constitute sorghum and millets are primarily the staple food for millions of marginalized people in Africa and Asia. They are the dominant cereal grains grown and constitute the largest source of calorie intake among smallholder farmers in semi-arid regions. However, despite the various nutrients that are associated with consumption of these grains, they contribute more to starch consumption and lack essential macro and micronutrients that are required for a healthy body. These essential micronutrients can be harnessed from legume and oil seed crops. Like many other cereals, millet and sorghum are high in carbohydrate content, making them useful components of dietary energy balance in foods. Value addition targeting these cereals through milling and fermentation will enhance nutritional value of the crops and eventually enhance individual nutrition. The blending of small grains with legumes and oil seed crops such as sesame as localised low cost food fortification initiatives would compensate for the deficiency of certain micronutrients such as vitamins, magnesium, calcium, and zinc. Neglected oil seed crops such as sesame can be processed into an array of nutritious food products using low cost technologies. These include producing butter, oil and other products that can be blended with cereals. Successful improvement of these attributes would be instrumental in expanding the spectrum of use of small grains, legumes and oil seeds. Future trends should focus on small grain consumption in the developed countries and non-small grain-producing areas that could help the production and utilization of these crops.

Legumes like cow peas and groundnuts as well as oil seed crops such as sesame have a huge potential in addressing micronutrient malnutrition among smallholder farming communities through value addition and food fortification of cereals. The existing food fortification initiatives that are targeted by national food fortification strategies do not consider the use of small grains and neglected legumes as well as oil seeds. While maize and wheat are the preferred food fortification vehicles, small grain cereals must be considered in the national and local food fortification strategies of developing countries since maize and wheat are crops that cannot grow well in semi-arid regions.

There is a huge socio-economic benefit of promoting value addition and fortification of cereals using neglected food crops such as sesame, cow pea and groundnuts among smallholder farmers as these crops thrive well in the marginal areas that are characterised by erratic rains and poor soil fertility. There is potential in improving household income through marketing some of the products that are produced from value addition and food fortification especially when the target market is the non-small grain-producing community. The additional income derived from such value addition can be used to supplement the diets of the smallholder farmers with some items that can be bought from the market.

Further studies on this subject need to establish good agronomic practices and proper post-harvest handling and storage of these crops since there is a lack of empirical evidence with regards to this. This will enhance availability as well as preserving their nutrient content especially with regards to sesame and groundnuts that have high oil content. Scholars also need to explore diverse value addition options that unlock the nutritive value of these neglected food crops at household level. Scientists focussing on food fortification using cow pea, sesame and groundnuts as micronutrient vehicles need to analyse the bioavailability of their nutrients, anti-nutritional factors and the shelf life of the products produced.

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Declaration of competing interest

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