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Promoting millet, an underutilized crop. A review of food-based approach in combating micronutrient deficiency

Promoción del mijo, un cultivo infrautilizado. Una revisión del enfoque alimentario para combatir la carencia de micronutrientes

Jumoke ILO[1]

Abiodun Famakinwa[2]

[1]Federal University of Agriculture Jumoke.famakinwa@yahoo.co.uk

[2]Cape Peninsula University of Technology biofamar@gmail.com

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Resumen La malnutrición de micronutrientes es un problema mundial más grave que el hambre, y tiene consecuencias duraderas para las sociedades. Este estudio examina el uso de técnicas para combatir la carencia de micronutrientes de los alimentos. Se revisó una muestra de la bibliografía existente, donde se destacan algunas conclusiones y se identifica las lagunas de conocimiento y los objetivos de investigación que han sido abordados para resolver el problema mundial de la carencia de micronutrientes. Un método más reciente consiste en utilizar procesos revolucionarios de elaboración de alimentos para producir comidas ricas en micronutrientes utilizando cultivos alimentarios infrautilizados o locales, como el mijo, que pueden prevenir numerosas carencias de micronutrientes sin riesgo de interacciones antagónicas ni de pérdida de nutrientes.

Palabras clave: Enfoque basado en los alimentos; carencia de micronutrientes; mijo; cultivos infrautilizados; elaboración de alimentos.

Abstract Malnutrition of micronutrients is a global problem that is more serious than hunger and has lasting consequences for societies. This study reviews existing interventions, where traditional grains are being promoted to establish their importance and promote their use as food. It examines a sample of existing literature, highlights, some key takeaways, and identifies knowledge gaps and research objectives in order to solve the global problem of micronutrient deficiency. A more recent method is to use revolutionary food processing processes to produce micronutrient-rich meals using underutilized or local food crops like millet, which can prevent numerous micronutrient deficits at the same time without the risk of antagonistic interactions or nutrient loss.

Keywords: Food-based approach; micronutrient deficiency; millet; underutilized crops; food processing.

Introduction

Food-based techniques that successfully lead to year-round access to, availability of, and consumption of nutritionally acceptable amounts and variety of foods have several economic, social, and health benefits. Individuals' nutritional well-being and health are encouraged, and their earnings and lives are greatly aided. It is a truth that food-based malnutrition prevention solutions have yet to be fully designed, tested, implemented, scaled up, and proven to address the nutritional deficiencies of the world's poorest populations (Thompson & Amoroso, 2014).

Malnutrition refers to a lack of proper nutrition, which can include undernutrition, overnutrition, and specific deficits (or excesses) of vital nutrients including vitamins and minerals. Micronutrient malnutrition is defined as a lack of vitamins and/or minerals that are important for public health. These include, but are not limited to vitamin A deficiency, vitamin D deficiency, iodine deficiency disease (IDD), zinc deficiency, and iron deficiency (anemia). The majority of micronutrient deficiencies affect poor and disadvantaged households whose members are unable to purchase or produce sufficient food, who live in marginal or unsanitary environments with limited access to clean water and basic services, and who lack access to appropriate education and information (World Health Organization [WHO], 2020).

More than 2 billion individuals worldwide are affected by micronutrient malnutrition, which has a negative impact on their health and survival. Globally, all children under the age of five are at risk of one form of nutrient deficiency or another, with rickets cases on the rise, particularly among dark-skinned people; approximately 2 billion people are zinc deficient, one billion have iron deficiency (anemia), and 250 million are iodine deficient (Abubakar *et al.*, 2017).

It's critical to comprehend the scope and nature of the problem, as well as the solutions to micronutrient insufficiency. Micronutrient deficiency occurs when vitamin and mineral intake or absorption is insufficient to maintain optimal health, development, cognatic functioning, and normal physical functions. Micronutrient deficiencies are known as hidden hunger because they build gradually over time (Ibeanu *et al.*, 2020). The consequences of this deficit are sometimes undetected until irreversible harm has occurred in the body. Diseases including osteomalacia, thyroid disorders, anemia, zinc deficiency, and vitamin A deficiency are just a few of the consequences. Hidden hunger accounts for 7% of the world's illness burden (Ibeanu *et al.*, 2020).

Furthermore, hidden hunger jeopardizes an individual's socioeconomic growth, learning aptitude, and productivity (Ekholuenetale *et al.*, 2020). Given the importance of micronutrients, particularly vitamin A, iron, iodine, and, more recently, zinc, their non-correctable deficiencies continue to be a major public health issue in Nigeria, making any strategy for health, education, and prosperity a major challenge (Federal Ministry of Health Department of Family Health Nutrition, 2013).

When people can't afford a variety of meals that include enough vegetables, fruits, or animal-source foods that are high in micronutrients, deficiencies like those observed in tuber-based diets or monotonous cereals are common. Unfortunately, in many nations grappling with widespread malnutrition, costly, ineffective, and unsustainable treatments are all too prevalent (Thompson & Amoroso, 2014).

Food-based approach to address micronutrient malnutrition

Food diversity, supplementation, food fortification, and biofortification can all help with micronutrient deficits. Iron, vitamin A, and zinc deficiency have been identified as public health issues among Nigerian schoolchildren (Onabanjo & Balogun, 2014; Akeredolu *et al.*, 2011; Ayogu & Onah, 2019). A child low in micronutrients may be able to attend school and participate in school activities, but the output will be far from satisfactory due to the effects of these deficiencies on growth, development, and the physiologic processes of the entire body. Different intervention techniques have been developed and applied to reduce micronutrient deficiencies, but nutrition remains the most powerful adaptable environmental exposure to target in order to lessen the burden of diseases and death caused by these deficiencies (Bailey *et al.*, 2015). It is critical to advocate for the use of food-based techniques to meet optimal dietary requirements and alleviate micronutrient deficiencies (Ross, 2013).

Supplementation, food fortification, dietary diversification, crop diversification, and the utilization of indigenous and traditional foods are examples of such initiatives. Food-based strategies that increase diet diversity are a cost-effective and sustainable option for controlling and preventing micronutrient malnutrition, according to international agencies, non-governmental organizations (NGOs), and funders. Food-based techniques, such as dietary variety and food fortification, are sustainable solutions for improving people's micronutrient status, according to the Food and Agricultural Organization. Micronutrient status and overall nutrition can be improved by improving the availability of, expanding access to, and eating a range of micronutrient-rich foods (Thompson & Amoroso, 2014).

Agriculture-based techniques and diversification strategies are two ways to promote sustainable food-based approaches to enable optimal micronutrient consumption by a bigger population. Dietary diversification can be achieved by encouraging household food production, which includes things like home gardens, small animals, fishing, and food preservation and processing (Shetty, 2011). Food-based techniques are defined as a sustainable approach because they enable people and households to assume ultimate responsibility for the quality of their diet by producing nutrient-dense foods and making well-informed food choices. These tactics are referred to as the ideal long-term aim that society strives for ensuring access to a nutritionally adequate diet through the availability of a diverse range of foods, adequate feeding, and good preparation. Multiple nutrients, such as dietary energy, proteins, and other micronutrients, can be addressed simultaneously with food-based techniques without the risk of antagonistic nutritional interactions or excess (Thompson & Amoroso, 2014).

Food-based solutions to address micronutrient insufficiency include a wide range of interventions aimed at increasing the availability, production, and access to micronutrient-rich foods, as well as the consumption of micronutrient-rich foods and their bioavailability in the diet. In countries like Nigeria, cereal foods like biscuits and bread are particularly popular, especially among the snack-eating population (children and adolescents). These selected cereal foods are still poor providers of micronutrients without fortification. Although iron fortification of flour is widely considered one of the most efficient and low-cost micronutrient interventions, most identified settings also have other micronutrient deficiencies. This necessitates a straightforward strategy for dealing with numerous micronutrient deficiencies. (Ayogu *et al.*, 2018). Traditional grains have gotten very little attention in terms of research. These are grains that have been proven to have sufficient nutritious content to correct micronutrient deficiencies in people of all ages. As a result, this study will look at existing interventions that promote traditional grains in order to establish their value and encourage their usage as food.

Methodology

The review looked for published studies on the utilization of pearl millets and other underutilized crops in addressing micronutrient deficiency in children in Nigeria, Africa, and other selected continents in international and local electronic sources. Studies carried out on micronutrient malnutrition, pearl millets, and sorghum. Feeding trials between 2010 and 2020 were given priority. It examines some existing literature, highlights some lessons learned, and identifies knowledge gaps and research objectives in order to solve the global problem of child malnutrition due to micronutrient deficiencies.

Results and discussion

Micronutrient deficiency interventions

Nigerian researchers are looking into children's nutritional conditions, particularly macro and micronutrient deficits. Gegios *et al.* (2010), for example, studied "children consuming cassava as a staple food are at risk for inadequate zinc, iron, and vitamin A intake". For the entire population of children aged 2 to 5 years, 33% had an appropriate vitamin A consumption, 45 percent had an adequate iron intake, and 37% had an adequate zinc intake. Increased 20-fold for -carotene and 4-fold for iron and zinc if biofortified, and recalculated nutrient intake and dietary cost calculations. Vitamin A deficiency would affect 61 percent of the population, while iron deficiency would affect 86 percent and zinc deficiency would affect 67%. According to the findings of the cost analysis, appropriate levels of vitamin A, zinc, and iron may be obtained for $0.74 per day in Kenya, $0.64 per day in Nigeria, and $0.53/day if cassava is biofortified. Cassava consumption was found to be negatively associated with vitamin A, iron, and zinc intake, indicating that it is a risk factor for micronutrient insufficiency. When a standardized scoring system was used to evaluate the diets of Nigerians and Kenyans, both countries' diets were found to be lacking in diversity. Inadequate dietary intake of a micronutrient does not always imply clinical nutritional inadequacy, according to the Kenyan and Nigerian respondents. “A multi-micronutrient beverage improves the vitamin A and zinc status of Nigerian primary school students”, said Aaron *et al.* (2011).

It was a school-based, double-blind, placebo-controlled trial including 250 children aged 5 to 11. Children were given a de-wormer, 250ml multi-micronutrient beverage, or a placebo beverage five days a week for six months before intervention. Because of their high bioavailability, iron and zinc chelates were initially chosen; however, to save money, less expensive forms of iron and zinc were mixed with the chelates. Precooked maize and soy protein isolate in a proprietary combination with added vitamins and minerals. During the six-month intervention period, there were no significant differences in weight increase, linear growth, or anthropometric indicators. The self-reported prevalence of diarrhea, malaria, and upper respiratory illness did not differ significantly between groups.

When comparing children in the micronutrient group to children in the control group, the prevalence of vomiting was higher after the intervention. The prevalence of children with increased c-reactive protein values did not differ between groups after the intervention, nor did it differ significantly from baseline. After 6 months, the intervention had no effect on hemoglobin or serum ferritin concentrations. The multi-micronutrient beverage had a positive effect on serum retinol and zinc concentrations. However, there was a possibility that one or more of the beverage's micronutrients may have hampered iron absorption. In the analysis, the effects of subclinical infection were not entirely controlled for. Controlling for CRP and a 1-acid glycoprotein is required to determine the effects of subclinical inflammation on serum ferritin (AGP) due to the fact that increased AGP is more common in children.

Ziauddin *et al.* (2007) worked in Bangladesh on a project called "A multiple-micronutrient-fortified beverage affects haemoglobin, iron, and vitamin a status and growth in adolescent girls in rural Bangladesh". Subjects were randomly assigned to either a fortified or non-fortified beverage (orange-flavored powder, only differing in color) group for six days per week for twelve months at the schools in a randomized, placebo-controlled, double-blind study (no drink during school holidays). The orange-flavored powdered drink was supplemented with several micronutrients and sold in sachets (45 g). The prevalence of anemia, iron deficiency, and iron-deficiency anemia in the enriched beverage group fell by half after a six-month intervention phase, with no meaningful change in the second six months. The prevalence of anemia in the non-fortified beverage group differs from the baseline after six months, but continues to rise at the twelve-month follow-up examination. Despite the food fortification intervention, 12.2% of fortified beverage drinkers and 20.5 percent of non-fortified beverage drinkers were still anemic. In addition, serum zinc levels in both groups declined between six and twelve months.

The amount of zinc taken could be the source of a putative iron-zinc interaction, resulting in inadequate zinc absorption (inconsistent level of the micronutrient). This is a restriction of micronutrient intervention in food fortification. The impact of micronutrient fortification of yogurt on micronutrient status markers and growth in Bangladesh was studied by Sazawal *et al.* (2013). It was a randomized, double-blind, controlled trial that took place in six primary schools with classes ranging from kindergarten to fourth grade (6-9 years). For a period of twelve months, the children were fed both micronutrient-fortified and non-fortified yogurt. Iron, zinc, iodine, and vitamin A were all 30 percent of the RDA in the 60 g yogurt consumed daily. Because there was no iron deficiency at the start, it was unable to assess its impact on iron status. Improved hemoglobin concentration indicates improved iron utilization, which could be due to the availability of vitamin A and zinc. A total of 400 children were recruited in order to identify a 2.6 g/L increase in mean hemoglobin levels, a 38 percent reduction in iron deficit, and a 37 percent reduction in zinc deficiency.

Van der Hoeven (2014) investigated the impact of African leafy vegetables on the reduction of micronutrient deficits in schoolchildren in South Africa's North-West province. The study used a randomized controlled design with 171 kids as participants. For 62 school days, children in the experimental group were provided 300 grams of a cooked ALV dish with the starch of the school meal, whereas children in the control group were fed the regular school meal. African leafy vegetables had no effect on serum retinol, ferritin, or hemoglobin levels. Despite the population's low zinc status, African leafy vegetable consumption had no effect on serum zinc concentrations. For serum retinol and serum ferritin, there was no difference between baseline and endpoint values.

Despite the fact that the African leafy vegetable dishes appeared to be high in micronutrients and that this group has (moderate) micronutrient deficits, children from a rural agricultural community's micronutrient status did not improve after three months of intake. The high phytic acid content of maize meal is thought to be the most important dietary component influencing the absorption of native and fortified iron and zinc, especially in a plant-based diet. In addition, the study population's micronutrient status was better than expected. Because the control meals had more variety, adherence to the intervention meals waned toward the end, most likely due to product weariness.

Researchers in Nigeria who studied staples were evaluated. Levels of iron (Fe) and zinc (Zn) in staple cereals: Micronutrient deficiency implications in rural Northeast Nigeria were investigated by Musa *et al.* (2012). The grains were chosen at random from the open market and tested for iron and zinc levels. In Borno and Yobe states, maize, pearl millets, rice, and sorghum are grown locally.
The contents of iron and zinc were determined by Flame Atomic Absorption Spectrometry (FAAS). The highest mineral content was found in sorghum and pearl millets, which had similar iron concentrations. Pearl millet had the highest zinc content, while rice had the lowest. Pearl millet and sorghum were found to be more nutritious than maize and rice from Northeast Nigeria based on vital trace content. In order to improve the bioavailability of these micronutrients, processing procedures that minimize anti-nutrients like phytate in cereals should be examined.

Jaryum *et al.* (2016) conducted a study on the comparative analysis of certain trace element levels in basic cereals grown in Plateau State, Nigeria. The goal of the study was to examine and assess the differences in the mineral element content of several grain meals grown in North-Central Nigeria (rice, maize, guinea corn, and finger pearl millets). Using an atomic absorption spectrophotometer to evaluate iron, zinc, and calcium content, Guinea corn had the greatest mineral level, followed by pearl millet, and rice and maize had the lowest mineral levels. In Ogun State, Agbon *et al.* (2009) investigated the micronutrient content of traditional supplemental foods.

The goal of the study was to find out which cereals were most usually used in the creation of Ogi in the study community, as well as provide information on the iron, zinc, and calcium content of the cereal pap using data from 150 breastfeeding women. Atomic Absorption Spectrophotometry was used to determine the concentrations of iron, zinc, and calcium. Traditional supplementary foods included pap made from white and yellow maize, pearl millets, and sorghum. Sorghum pap was favored by 42 percent of the women above other pap, while pearl millet was the least used while having the highest nutritional content.

Need for novel food processing and preparation of underutilized crops

Novel processing and preparation methods, such as extrusion and sourdough fermentation, have enormous potential for transforming underutilized crops into a wide range of high-quality snacks and products, such as bread and biscuits, that provide convenience, taste, texture, color, shelf-stability, and increased micronutrient concentrations at a low cost. Because these crops are familiar to the local populace, their cultivation, consumption, and acceptability as sourdough and/or extruded snacks should not be an issue.

Advocacy for the use of these improved snack attributes as a vehicle for micronutrient intervention during school meals may be critical. A biscuit is regarded as a snack, and it is simple to distribute and store. It also is simple to keep track of, making it less vulnerable to abuse. Because it is viewed as a snack rather than a meal, biscuits can be used to fight micronutrient deficit. As a result, they are unlikely to replace meals provided to the child at home. Biscuits also have the advantages of requiring little preparation, being easy to distribute, and having a long shelf life (Goyle & Prakash, 2011).

Millets as an underutilized crop

Millet is the world's sixth most important cereal crop. Millets are major crops throughout Asia and Africa, particularly in India, Nigeria, and Niger, where they account for 97 percent of millet output. For the past 10,000 years, they have been cultivated in East Asia. India is the world's leading millet producer (Sarita, 2016). Nigeria has been identified as the world's second-largest millet grower, after India (Table 1). Millets were one of the earliest foods known to humans, but with urbanization and industrialization, they were replaced by rice and wheat. The most important millets are pearl millet, foxtail millet, and finger millet. These crops can withstand a wide range of temperatures, moisture regimes, and soil fertility conditions, and they produce consistent yields. Gluten-free pearl millet is one of the most easily digestive and non-allergenic cereals available (Ameh *et al.*, 2013; Michaelraj & Shanmugam, 2013; Yacob & Timothy, 2017).

Tabla 1

The Statistical Division. Top 10 millet producers, 2013

Country	Production (Tons)
India	10,910,000
Nigeria	5,000,000
Niger	2,955,000
China	1,620,000
Mali	1,152,331
Burkina Faso	1,109,000
Sudan	1,090,000
Ethiopia	807,056
Chad	582,000
Senegal	572,155
World	29,870,058

Note. Thompson & Amoroso (2014).

Panicum glaucum, sometimes known as pearl millet, is a grass that grows in warm areas all over the world. The annual plant *Panicum glaucum* has a shallow, fibrous, and flat root. Pearl millet, Finger millet, Foxtail millet, Kodo millet, Little millet, Barnyard millet, Sorghum, and Proso millet are some of the numerous types of millets grains grown in Africa and India (Yacob & Timothy, 2017). Millets are an important food component in many African and Asian locations, with millet-based traditional dishes and beverages (fermented or unfermented), porridges, and snack foods popular among the less affluent (Shahidi & Chandrasekara, 2013). B vitamins, copper, potassium, iron, phosphorus, magnesium, zinc, and manganese are all abundant in millet. Millet has long been a staple in many cultures, but research into its nutritional benefits and application is still in its early stages (Yacob & Timothy, 2017). Due to higher levels of protein with a more adequate amino acid profile, dietary energy, vitamins, insoluble dietary fiber, several minerals (especially micronutrients such as iron and zinc) leading to a lower glycemic index, and phytochemicals with beneficial antioxidant properties, pearl millet grains can be comparable or even superior in terms of nutrition content to major cereals such as wheat and rice.

Millet may be turned into a wide range of delicious foods, especially when combined with a small amount of wheat. It can be extruded into snacks, ready-to-eat foods, and other products. Because pearl millets lack gluten protein, they cannot be used to manufacture yeast-leavened bread. Millet is one of the world's oldest grains. Meanwhile, highly variable demand and supply situations have resulted in wheat supply interruptions and price increases, putting wheat-importing countries like those in Sub-Sahara Africa at risk of food insecurity as they rely on higher imports to meet rising wheat demand (Negasia *et al.*, 2013).

For this study, researchers looked at several previous studies that compared underused millet grains to more often consumed grains. Levels of iron and zinc in staple cereals. Micronutrient deficit implication and comparative examination of some trace element content of stable cereals were studied by Musa *et al.* (2012) and Jaryum *et al.* (2016), respectively. Flame Atomic Absorption Spectrometry (FAAS) was used to examine maize, pearl millet, rice, guinea corn, and sorghum, among other grains. Pearl millet had the highest zinc and iron concentrations, whereas sorghum and Guinea corn had the highest iron concentrations. Rice and maize had the lowest zinc and iron concentrations. The presence of phytic acid and polyphenols affects the bioavailability of iron and zinc, among other things. In a systematic review of the "Potential functional implications of pearl millet in health and illness".

Nambiar *et al.* (2011) found that, despite its high micronutrient content and necessary amino acids, pearl millets are underutilized and compete with rice and maize. Pearl millets' nutritional content, health benefits and processing, selected products, and nutraceutical value for enhanced human health were examined by Issoufou *et al.* (2013) and Bora (2014). Pearl millet is said to have a high quantity of vitamins, minerals, fatty acids, dietary fibers, high-quality essential amino acids, great nutritional quality, and various health benefits when compared to wheat and rice (anti-inflammatory, anti-microbial, novel treatment of blood pressure, diabetes, etc.).

Limitations include commonly utilized processing procedures that result in significant nutritional loss, preventing increased pearl millet usage. Pearl millet grains are regarded as traditional food and a low-status food, and they are mostly ignored in science, agricultural programs, and policy. "Pearl millet grains: nutritional quality, processing, and potential health benefit" (review) and "Sorghum and Pearl millet food research failures and successes" (meta-analysis) were researched by Ameh *et al.* (2013) and Rooney *et al.* (2012), respectively. When compared to main grains like rice and wheat, Ameh *et al.* (2013) found pearl millets to have a high nutritional value. And that pearl millets' nutritious content makes them suited for large-scale use in the production of food products such as extruded snack food and infant meals. Premium pearl millet goods that match consumer needs of a food product-convenience, taste, texture, color, and shelf-life are frequently not available in metropolitan areas, according to Rooney *et al.* (2012). The stigma of pearl millet as a poor man's diet can be dispelled by creating a more appealing and enhanced product.

Anti-nutritional factors in millets

Due to the presence of antinutritional agents, millet has a low bioavailability despite its high nutrient content. Phytate is found in seeds (seed coat and germ), roots, and tubers as a naturally occurring organic molecule. Mineral elements such as zinc, iron, magnesium, and calcium create near-soluble or insoluble compounds with it. The majority of phosphorus in cereals is said to be in the form of phytic acid, which is unavailable to the human body. Because phytates interact with proteins, their availability is reduced. Phytate concentration in different pearl millet cultivars reported by different studies ranges from 354 to 857 mg, 100g-1 kg (Aggarwal, 1992; Kumar & Chauhan, 1993; Poonam *et al.*, 2002; Rani *et al.*, 2018).

Certain food processing activities, such as germination, heat treatment, fermentation, milling, and germination, have been found to reduce the amount of phytate in plant material (Rani *et al.*, 2018). Polyphenols are a prominent antinutritional factor because they block the activity of various hydrolytic enzymes, including amylase, cellulose, trypsin, chymotrypsin, and galactosidase, as well as forming tannin protein complexes, which limit starch and starch consumption. Vitamin and mineral availability is reduced by phenols. Low starch and protein digestibility have been documented in millet, which can be ascribed to antinutritional components in grains (Common Fund for Commodities & International Crops Research Institute for the Semi-Arid Tropics, 2003).

Value addition and extruded products from pearl millets

In terms of minerals, vitamins, and dietary fiber (water-soluble/insoluble), pearl millets are nearly 3-5 times nutritionally superior to wheat and rice due to their micronutrient concentration. When compared to roasted weaning foods, the extrusion technique enhanced the iron availability of extruded weaning foods based on pearl millet, peanut, cowpea, or milk powder by 3.5 to 6.5 times (Pathak & Kochaar, 2018). Using an experimental approach, Sawant *et al.* (2013) investigated "Physical and sensory aspects of ready-to-eat meal created from finger millet-based composite mixer by extrusion". Ready-to-eat nutrition extruded snack was made using a mixture of finger millets, maize, rice, full-fat soy, Bengal grain, and skimmed milk powder. Protein and minerals were found to be sufficient. There was also a difficulty with the flour mix ratio. "Development of protein-rich ready-to-eat extruded snacks using a composite blend of rice, sorghum, and soybean flour", according to Omwamba and Mahungu (2014). A satisfactory nutritional profile and amino acid retention were reported. It was decided to employ an experimental design. The flour mix ratio presented a problem.

Omah (2012) worked on the development and testing of baked and extruded snacks made from pearl millet, pigeon pea, and cassava cortical flour blends. The protein levels, as well as all mineral and vitamin products, were kept better in extruded snacks than in cookies, according to the study. Hot extrusion is a high-temperature, short-time method that minimizes nutrient loss. The anti-nutrients in the prepared samples were reduced by baking and extrusion, although not to the maximum extent possible. Lack of quality grain supply, nutritional myths such as poor digestibility, few shelf-stable convenience foods, unavailability of extension of existing processing technology, governmental policy, logistics and markets issues, poor image of sorghum and pearl millets, and grain storage facilities are some of the challenges that extrusion processing faces in developing economies (Pathak & Kochaar, 2018). However, at the national level, extrusion technology should be incorporated into food.

Conclusion

Any sustainable plan to reduce micronutrient deficiencies must include strategies to improve the availability, access to, production, and usage of locally accessible foods with high micronutrient content and bioavailability that accomplish desirable micronutrient intakes and health outcomes. Changes in eating behavior through communications, social marketing, or nutrition education are among the approaches used in these types of strategies, as are changes in traditional domestic methods for preparing and processing indigenous and underutilized foods Underutilized crops like pearl millet grains were found to have more nutritional content and potential health advantages than major cereals like rice, wheat, and maize.

However, consumption of these underutilized crops as food is restricted to rural communities and households. Despite their high nutritional value, their potential worth has been underestimated and underutilized due to a lack of attention. As a result, their deterioration can have immediate effects on the poor's nutritional status and food security, jeopardize better nutrition, and raise fears of hidden hunger in a world that is becoming increasingly populated, impoverished, and subject to significant climatic uncertainties. Many civilizations have long relied on underutilized grains like pearl millet, but study into its nutritional worth and application is still in its early stages.

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