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Full Length Research Paper

The Magnitude of Post-harvest Groundnut Loss in Africa and How it Affects the Security of Food and Nutrition

Eskender and Lencho

Instituto Bule Hora University, Bule Hora, Ethiopia

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By lowering post-harvest loss, resources including financial, human, and natural inputs are preserved, which lowers poverty, increases household incomes, and enhances rural livelihoods. Groundnuts are preferred for improving nutrition because of their higher fiber value, higher unsaturated fat content, and plant-based protein. Because it fixes nitrogen from the air and improves soil fertility, groundnuts are also well known for their environmental benefits, which include lowering the need for chemical fertilizers. Nevertheless, there aren't many published scientific studies on the measurement of groundnut post-harvest loss in African nations. Furthermore, biodeterioration during storage was the main focus of published studies on groundnut post-harvest loss. Therefore, the purpose of this research was to evaluate the root causes, the degree of groundnut quality and quantity loss in the supply chain after harvest, post-harvest loss mitigation technologies in Africa, and their effects on food and nutrition security. According to this assessment, smallholder farmers in sub-Saharan African nations are constrained by the increased drudgery needed in the groundnut supply chain. Groundnut post-harvest losses, both qualitative and quantitative, are greater when groundnut pods are stripped and shelled, as well as when groundnuts are stored in warehouses and on farms throughout the supply chain. In African nations, post-harvest groundnut losses range from 8.9% in Ghana to 31% in Uganda. Because traders and processing facilities do not test for aflatoxin content after purchase, higher-quality groundnut producers do not obtain a higher market price, allowing them to disregard labor- and cost-intensive excellent agricultural practices. In conclusion, it is important to implement and supply better groundnut varieties, aflatoxin management methods, and post-harvest technologies that are more effective, less expensive, and locally accessible. Furthermore, there should be a broad public awareness campaign about aflatoxin toxicity and mitigating strategies.

Key words: Aflatoxin, Food and nutrition security Groundnut, Groundnut supply chain, Post-harvest loss.

INTRODUCTION

The For many impoverished nations, groundnuts (Arachis hypogaea L.), the sixth-most significant oil seed crop, provide both nutrition and revenue [1]. Because groundnuts contain 25–34% protein, 44–56% oil, and are a source of calcium, iron, thiamine, riboflavin, and niacin, they can be used to counteract protein and energy malnutrition in underdeveloped nations [1]. Edible oil is made from groundnuts, which are the second-largest source of vegetable oils after soybeans. The oil can be used for cooking, making peanut butter, and making confections. Groundnuts are also eaten with bread or biscuits, added to cookies, sandwiches, and candies, and used as frosting or icing. In Ethiopia, they are also used to make hot beverages in place of milk during fasting days, as well as in kid-friendly snacks.

can also be eaten roasted every day [1]. In human nutrition, groundnut cake can be utilized as a protein supplement [2]. Additionally, groundnut haulm is utilized as animal feed [3, 4]. Groundnut improves soil fertility and fixes nitrogen in the soil [3].

According to Fig. 1, China accounted for the largest portion of groundnut output (in shell) in 2021 (about 18 million tons), followed by Africa (16 million tones), India (10 million tons), and the United States (almost 3 million tons) [5]. Africa produced about 16 million tons of groundnuts in 2021, with an average yield of only 885.6 kg ha—1, compared to the global output of about 54 million tons with an average yield of 1648.1 kg ha—1 [5]. Numerous biotic, abiotic, and socioeconomic factors are linked to the decline in yield in Africa [1].

Post-harvest handling of groundnuts includes removing them from the ground, drying them on the farm, removing the pod from the haulm, moving them to the homestead, drying them even more there, storing them on the farm, shipping the produce to the market, shelling and storing them in a warehouse, and shipping the groundnut kernel and/or pod to the market until it is consumed. Poverty is reduced and food and nutritional security is improved in developing nations by evaluating the magnitude of post-harvest quantitative and qualitative losses in the groundnut supply chain and reducing losses at every stage of the supply chain. However, consumers are at risk for health problems due to aflatoxin contamination of groundnuts by Aspergillus flavus and Aspergillus par-asiticus. This, in turn, discourages groundnut exports, which ultimately impacts the livelihood of smallholder subsistence farmers in developing nations. For example, the trade prohibition on groundnuts with aflatoxin levels exceeding permissible limits costs Africa around 750 million US dollars annually [6]. Scientific studies on the evaluation of groundnut post-harvest loss in African nations are scarce. According to Tsusaka et al. [7], the majority of published research on groundnut post-harvest loss concentrated on storage-related biodeterioration. Furthermore, there is little information in the literature about groundnut losses in the supply chain, both qualitatively and quantitatively.

Therefore, this review's objective was to evaluate the magnitude and root causes of groundnut post-harvest quality and quantity loss in the supply chain and to highlight how crucial it is to reduce groundnut post-harvest loss in order to guarantee food and nutritional security in Africa.

Quantitative groundnut loss in the supply chain

The reduction in mass of groundnut kernels that would have been available for human consumption at various stages of the supply chain is indicated by quantitative loss or physical food loss; this loss may be unintentional due to non-compliance with standards or intentional [8].

From harvest to the farmer's homestead, including lifting, drying, stripping, and transportation, Tsusaka et al. from ICRISAT investigated the weight loss of groundnuts in Malawi.

Shelled nuts resulted in an average weight loss of 13.7% and an income value loss of 189.7 US dollars per hectare, according to Tsusaka et al. [7].

1.1. Quantitative loss during harvesting

During the groundnut supply chain, smallholder farmers use labor- intensive mechanisms such as a hand hoe to uproot groundnut on the farm, but it needs great care not to cause mechanical damage and bruise the groundnut pod in the soil during harvesting. A FAO study in Malawi revealed that uprooting groundnuts from the soil had a lower loss in quantity than other stages of the groundnut supply chain [13]. Har- vesting takes several days, and approximately 1.5% of groundnut pods are lost due to pests and rodents [11]. Table 1 shows that the average groundnut weight loss during harvest in Malawi was found to be 5.88% because of hand hoe usage problems, weed problems on the farm, and thieves stealing the groundnut on the farm [7]. Meanwhile, in Uganda, the mean groundnut loss during harvest was found to be 12.27% [9]. 73% of interviewed farmers believe that uprooting groundnut plants during late harvesting causes crop loss [14]. In addition, Malawian farmers refer to stripping, shelling, winnowing, and sorting processes as stages of groundnut post-harvest loss [14].

1.2. Quantitative loss during improper drying

Insect pests affect groundnut kernels and pods after improper drying during the supply chain, resulting in a loss of groundnut quantity and quality [13]. Improper drying paves the way for quality deterioration in subsequent stages of the groundnut supply chain. Tibagonzeka et al. [9] revealed that 93% of Ugandan farmers would rather dry harvested crops on bare ground than use drying materials such as plastic sheets and mats (to prevent contact with the soil) during sun drying, which reduces the aflatoxigenic fungi and aflatoxin contamination of the harvested pro- duce. In addition to mold proliferation, improper drying results in losses during storage and milling [15].

1.3. Quantitative loss during pod stripping

Groundnut pod stripping from the haulm by hand is a labor-intensive, high-quantity loss process that is usually carried out by women and children; pods are lost along with the haulm as underage children cannot properly detach all pods from the haulm [13,14].

In the meantime, separating contaminated, tiny, shriveled, and damaged pods and/or kernels reduces the produce's overall weight by roughly 5% [16]. According to Masters et al., there was a 5–15% weight loss in groundnuts in Ghana when the damaged, shriveled, small-sized, and infected kernels were sorted [17]. It has been reported that injuries, spills, breakage, and bruises caused 18% of groundnut post-harvest losses [11]. According to the Malawian study, the drying and stripping of the pod stages of the groundnut supply chain resulted in an average weight loss of 7.58%. The weight loss was caused by mice eating the groundnut, youngsters handling and stripping the groundnut carelessly, and farm personnel consuming the raw groundnut [7].

1.4. *Quantitative loss during storage*

Because insect and rodent pests can readily access traditional storage facilities in poor nations, as well as because rats can damage polypropylene bags and eat the groundnuts kept in them, higher quantity and quality losses are seen during groundnut storage on farms and in warehouses. For extended periods of time, traders keep shelled groundnuts in warehouses, making them more vulnerable to rodent and weevil assaults. This leads to a lower-grade groundnut with a greater loss of quantity and quality [13]. According to a loss assessment research conducted in three regions of Uganda, the average weight loss of groundnuts reported in Uganda was 18.87%, as shown in Table 1 [9]. After seven months of storage in Niger, Baoua et al. [18] discovered that the stored groundnut-infesting insects (Corcyra cephalonica and Tribolium casta-neum) were responsible for a 15.9% weight loss.

1.5. *Quantitative loss during shelling*

Because shelling pods by hand is exhausting and frequently causes thumb strain in shelling men and women, farmers often soften the pods by spritzing them with water, which reduces the quantity and quality of groundnuts. At the same time, it has been observed that sheller machines break and damage groundnut pods while shelling [13]. Additionally, Mofya-Mukuka & Shipekesa [19] observed that Zambian farmers lost groundnuts when they used mechanical shellers.
According to Tsusaka et al., one of the main steps of quantity loss in the groundnut post-harvest supply chain is shelling, winnowing, and sorting away the inferior-grade groundnut [14].

2. **Groundnut qualitative loss in the supply chain**

When the quality of groundnuts declines, their market value drops, their nutritious value decreases, or the producer or trader in the supply chain makes less money [8]. Groundnut quality loss is indicated by significant color and flavor changes, insect infestation, mold growth, punctured, shriveled, and damaged pods, high-moisture pods and/or kernels, and increased amounts of non-seed foreign debris mixed with the groundnut [16].
In addition to posing a major health danger, groundnut contamination with aflatoxin causes financial loss because groundnut exports are prohibited because they do not meet the permitted level. For example, Zambia used to export groundnuts to European nations, but due to a European Union limit on total aflatoxin (4 μg kg—1), it is no longer able to export them to other nations [19]. Long-term use of ground nuts tainted with aflatoxin causes hepatitis, liver cancer, immune system weakness, childhood stunting, and even mortality [20].

2.1. *Qualitative loss during harvesting*

One of the main causes of aflatoxin contamination in groundnuts after harvest is delayed uprooting after the crop reaches maturity [16]. Smallholder farmers in developing nations utilize hand hoes, which need skill to lift groundnut pods correctly without bruising or damaging them. Broken or damaged pods are susceptible to aflatoxin contamination and mold formation [13,20].
In Malawi, groundnuts are harvested using hand hoes in 31 days [13]; the longer the harvesting period, the more the groundnuts deteriorate.
In Zambia, peanut farmers are uprooting groundnuts faster and with less effort by utilizing ploughs with the disc removed for improved soil penetration [19]. According to Abass et al. [11], improper harvesting techniques and equipment cause the groundnut pod and/or kernel to crack, become injured, and lose quality.

2.2. *Qualitative loss during improper drying*

The excessively dried groundnut's grinding quality, oil quality, and seed germination are all negatively impacted by temperatures above 40 ◦C [7]. Inappropriate drying at warm temperatures between 24 and 28 degrees Celsius promotes the growth of Aspergillus species and aflatoxin contamination, according to Chiewchana et al. [21]. Proper drying after harvest and storing the properly dried produce in moisture-proof storage materials improves the quality and safety of the grains, which in turn affects the revenue of smallholder farmers as the price of the grains rises after safe storage of the produce several months later [22]. Elevated moisture content of stored agricultural produce is the main cause of mold growth in storage.

The drying of groundnut pods on the farm with the haulm and then drying them on bare ground without a covering material on the ground has exacerbated mold growth and aflatoxin contamination of groundnuts [19]. When pods and/or kernels are inadequately dried, farmers may tell because they change color (becoming black), flavor, and smell, and people who eat them get sick and are diagnosed with diarrheal symptoms [1].

After harvest, uprooted groundnut pods are typically left in the field for four weeks to sun-dry before being dried further at home. However, Africa's high relative humidity makes it easier for Aspergillus spp. to infiltrate agricultural produce, so drying the produce right away after harvest and maintaining a low moisture content at safe levels stops the fungus from growing and causing aflatoxin contamination [23].
After groundnuts are harvested, their moisture content must be quickly reduced from 30 to 50% (wet basis) by letting the haulm dry with the pods on the farm for two to five days. The pods are then separated from the haulm and dried with hot air to bring the moisture content down to safe levels [21]. Aflatoxin production and fungal growth occur when groundnuts are dried in rainy, humid weather [13]. Higher moisture content causes kernel browning and insect invasion in groundnuts [24].
Nonetheless, the majority of farmers do not believe that minimizing post-harvest losses in Africa requires adequate drying and sound post-harvest management techniques [11,16].

2.3. *Qualitative loss during pod stripping*

Because removing groundnut pods from the haulm by hand requires more work, women and their kids participate in the process; this leads to a higher quality loss because the kids who strip the pods break them because they can't carefully remove the pod from the haulm [13]. If there are any bruising or breaks on the pod during the process of removing it from the haulm, it will be extremely vulnerable to mold growth and contamination of the groundnut kernel with aflatoxins [16].

2.4. *Qualitative loss during storage*

The produce's aflatoxin level can rise as a result of high humidity and elevated temperatures, inadequate ventilation in the storage area, and storage pests [25]. High-moisture kernels and/or pods, a perforated roof, and reduced air circulation in storage rooms all contribute to mold growth and aflatoxin contamination [20].

Long-term storage of shelled groundnut in warehouses increases the groundnut's vulnerability to rodent and weevil attacks, lowering its grade and causing it to lose both quantity and quality [13]. Although groundnuts in pods are protected from bio-deterioration, once the shell is removed and stored, molds, insects, and rodents can quickly damage the groundnut because the kernel absorbs moisture. Additionally, groundnuts stored in polypropylene bags in homes with inadequate air ventilation are more likely to become contaminated with aflatoxin than those kept in granaries outside the home [19]. The germination capability of groundnuts stored with an initial moisture content of 8% decreases from 79% (0 months) to 57% (6 months) [26]. If the groundnuts are held in kernel form throughout the season and for an extended period of time, the issue of germination loss is exacerbated [20]. Increased temperature and moisture content, pest infestation, and mycotoxin (aflatoxin) contamination were the factors that led to the decline in quality of groundnuts that were stored [7]. Because damaged groundnut pods and/or kernels have a higher aflatoxin content than undamaged ones, it is best to separate them before storing them [27].

2.5. *Qualitative loss during shelling*

Because shelling groundnut pods by hand is difficult and can cause some thumb strain for laborers and women, farmers often soften the pods by spritzing them with water, which reduces the quantity and quality of groundnuts. In contrast, using a sheller machine is known to break and damage the pods during the shelling process [13, 24]. As a result, the damaged kernels are vulnerable to mold and insect damage, which causes groundnut kernels to biodeteriorate [24].

The significance of post-harvest technologies in reducing groundnut post-harvest losses

The Traditional African storage structures are constructed of wood, bamboo, thatch, or mud and have thatch or metal roofs raised higher off the ground. Polypropylene bags are also used, but because they are not moisture-proof, Aspergillus spp. can infiltrate agricultural produce and create the conditions for the subsequent production of aflatoxin. Additionally, reusing contaminated bags increases the risk of Aspergillus spp. spore proliferation [25, 28, 29]. Farmers are more likely to keep agricultural products in jute bags, which are known to support the growth of mold and other fungi by readily collecting moisture from the environment [22, 29]. This leads to a greater level of aflatoxin. The groundnut is stored in jute bags, polypropylene bags, and traditional granaries after farmers dry it in the field and at home. While East and Southern Africans store their harvested crops in wire cribs, underground pits, metal bins, aerated cribs made of wood, and smaller bags treated with cow dung ash, West Africans store theirs outdoors, in jute and polypropylene bags, in conical storage structures, on raised platforms, in pots, and in storage baskets [11]. However, the amount of crop storage in conventional granaries is decreasing because young people lack the necessary skills to build them, they take up more space, and they are less mobile in the event of a fire, flood, or other emergency [11].

With a moisture content of 7–9%, groundnuts should be stored at an equilibrium relative humidity of 65%. As equilibrium relative humidity and temperature drop, agricultural produce storage safety increases exponentially [22]. Aflatoxin control requires a maximum moisture content of 9% for unshelled groundnuts and 7% for shelled groundnuts; at the same time, groundnuts can be safely stored for a year by lowering the relative humidity to 70% and keeping the temperature between 25 and 27 ◦C [23]. Although insects can flourish below 65% equilibrium relative humidity, fungi cannot multiply and spread [22]. The best way to control Aspergillus species and aflatoxin development is to carefully handle groundnuts and ensure that they are properly dried [21]. The development of various hermetic storage bags, airtight containers that restrict oxygen availability for insects, molds, and grain respiration in the storage bag, and Purdue Improved Crop Storage (PICS) [29] resulted from the inadequacy of woven polypropylene and jute bags for controlling molds and insects and preserving grain quality. The effectiveness of PICS in reducing aflatoxin levels in maize and groundnuts and managing Aspergillus fungus was reported by Udomkun et al. [30]. According to Waliyar et al. [25], maintaining grain quality and safety requires a small-scale metal silo and the use of hermetic storage bags to prevent mold and aflatoxin in groundnuts.

Germplasm stores and seed companies can use silica gel and a forced air dryer to dry seed in humid climates. Additionally, drying beads with zeolites help lower the relative humidity of grains in moisture-proof storage containers close to zero by absorbing 20–25% of their dry weight and being reactivated by heat when needed [22]. In order to keep agricultural products from deteriorating and to guarantee their safety and quality, Bradford et al. [22] stressed the use of drying beads in a plastic or metal container. Agricultural produce loss is reduced to around 1% in storage buildings that properly regulate humidity and temperature [15]. Post-harvest losses cost Sub-Saharan African nations approximately $4 billion annually, which could be used to feed 48 million people [31]. Pest invasions in storage, on-farm pest attacks, and meteorological changes (unpredictable rainfall patterns) all have a significant impact on African farmers [11]. Agricultural production is also being impacted by factors such as inadequate handling and storage facilities, thieves, middlemen between producers and wholesalers, a lack of farmers' unions, a lack of information on the current market price, restricted access to credit, and an increased workload for women, all of which result in a decline in both quantity and quality after harvest [9].

increasing groundnut farming in Africa is being influenced by the increasing labor required to lift or uproot groundnut during the harvest, pod stripping, and pod shelling operations [14]. In their study of the supply chain constraints for groundnut production in Ethiopia's eastern and southern regions, Chala et al. [1] found that improper storage conditions, field drying, premature harvesting, and failure to sort damaged and shriveled groundnut kernels are the main reasons why groundnut quality deteriorates.

The quantity and quality of groundnuts produced in Ethiopia, according to farmers, are being negatively impacted by severe drought stress during flowering, a lack of better groundnut seed varieties, and improper pre- and post-harvest procedures [1,32].

Aflatoxin-induced groundnut loss is caused by a combination of factors, including poor agricultural practices, high temperatures and humidity in the tropics, and inadequate pre-harvest and post-harvest management [19].

Because groundnut traders and processors do not test for aflatoxin content when buying groundnut from producers, groundnut farmers are not rewarded with a higher price for providing aflatoxin-safe groundnut on the market. As a result, groundnut producers are not interested in implementing the labor-intensive and expensive pre- and post-harvest good agricultural practices (GAP) [19].

Aflatoxin's negative health effects on consumers are not known to groundnut farmers, who, for example, submerge groundnut pods in water to facilitate pod removal during shelling. Some farmers may even intentionally mist kernels with water to increase their weight and, thus, their profit margin. Due to this situation, unshelled groundnuts were bought by groundnut processing facilities [1,13].

About 78% of Eastern Ethiopian farmers surveyed by Mohammed et al. [33] were ignorant of how incorrect drying and storing affect fungus development and aflatoxin contamination. But according to a Ugandan study, most farmers were aware of the benefits of drying crops on raised platforms or tarpaulins, but few were seen to employ them because the market did not offer higher-quality crops at a better price [9].

By competitively protecting the groundnut from the invasion of toxigenic fungal strains, biocontrol using non-toxic fungal strains is known to lower the aflatoxin concentration to 70–90% on the farm and in storage [34]. In the meanwhile, farmers in developing nations with limited resources benefit greatly from aflatoxin-resistant groundnut varieties, which also help to lower post-harvest losses [34]. It is advised to combine resistance breeding of groundnuts with other aflatoxin control methods because aflatoxin-resistant cultivars do not completely eradicate aflatoxin in groundnuts [35].

Aflatoxin control and the reduction of groundnut quality loss are facilitated by irrigation, fertilizer, and pesticide use, as well as by timely harvesting, appropriate weed control, insect control, and pre- and post-harvest management [34]. Aflatoxin can be prevented and controlled by using desiccants (silica gel and calcium chloride), reducing the moisture content of shelled groundnuts to 7% and unshelled groundnuts to 9% with equilibrium relative humidity at 70% and temperature of 25–27 ◦C, sorting out small, damaged, or shriveled groundnut kernels and/or pods using electronic sorting or manual picking methods, fumigating with fire smoke and chemical fumigants, and using antifungal compounds (5% Sodium Ortho Phenylphenate (SOP) solution, cinnamon oil, clove oil, eugenol, and methyl eugenol).

Aflatoxin concentration can be decreased by 40–80% by removing undersized, shriveled, discolored, and damaged kernels and/or pods; however, this sorting process can cause up to 5% of the groundnut mass to be lost. Guchi [16] and Florkowski & Kolavalli [34] observed the widespread use of groundnuts tainted with aflatoxin for making peanut butter and other foods.

In spite of the tremendous amount of work that African farmers put into growing groundnuts—which involves a lot of manual labor for weeding, harvesting, and shelling—traders who purchase the produce may use phony weighing scales, which lowers the amount of money that farmers should receive for their labor [19].

Before groundnuts are exported overseas, the healthy kernels are separated from the abnormal ones using dry blanching and sorting. However, the low-graded groundnut kernels are sold at a lower price than the healthy ones in the domestic market, and the low-quality kernels do not leave the groundnut supply chain and value chain; instead, the inferior groundnut may be used to make peanut butter, endangering domestic peanut butter consumers [36].

Lack of improved varieties, improper pre- and post-harvest procedures, plant disease and mycotoxin contamination, field and storage pests, and moisture stress during the groundnut blooming stage are the main factors limiting groundnut production in Africa. The profitability of groundnut production is ensured by groundnut farmers' traditional knowledge of how to distinguish between different varieties, seeds, and growth sites, as well as how to determine physiological ripeness for harvest [1,37]. A well-established groundnut plant breeding policy, the adoption of groundnut processing technologies, adequate groundnut seed availability, improved post-harvest management practices, a well-thought-out policy on groundnut production and marketing, proper use, and direct farmer-to-groundnut market connections without the involvement of middlemen were all suggested by Minde et al. [38].

Compatible Technology International (CTI) has developed a groundnut sorter that is six times more efficient than hand sorting, a screen stripper that is 1.5 times more efficient than stripping groundnuts by hand, and an oxen-driven lifter that is nine times more efficient than lifting with a hand hoe. Additionally, CTI claims

that using the aforementioned technologies reduces drudgery by nine times, saving farmers' labor, energy, and time, especially women [39]. Two of the shellers are the disc sheller, which is 24 times more efficient, and a drum sheller, which is selectively preferred by women, which is 14 times more efficient than hand shelling.
The use of post-harvest technologies in Africa is limited by a number of factors, including higher costs for buying and renting them, transportation, a lack of technical support, theft, the fact that some technologies are only appropriate for men, a lack of practice using them together, a lack of training on the technologies, a lack of interest in forming unions, and the lower efficiency of some technologies (manual groundnut shellers) [8].

Maintaining groundnut quality contributes to increased output and better living conditions

Because up to 95% of Africa's agriculture depends on rain-fed agricultural production and frequent droughts, the continent is particularly vulnerable to climate change [40]. By lowering greenhouse gas emissions, prolonged usage of plant proteins like groundnuts can lessen the effects of climate change on crop yield and production globally, and in Africa specifically [41].
Legumes' ability to fix nitrogen is essential to the sustainable and lucrative intensification of agriculture in sub-Saharan Africa [42]. Because it fixes nitrogen in the air and improves soil fertility, groundnuts are widely recognized for their environmental value and for lowering the need for chemical fertilizers. By rotating crop production with groundnuts, resource-poor farmers in developing nations can lower the expense of chemical fertilizer [43]. Because groundnuts fix nitrogen during production, less chemical fertilizers are used, which lessens the harm that chemical fertilizers have to people, animals, aquatic life, and the environment overall [44]. In order to reduce the depletion of natural resources and greenhouse gas emissions of nitrous oxide, biological nitrogen fixation must be used in place of nitrogen fertilizer derived from fossil fuels [42]. On the other hand, farm management techniques including crop rotation, intercropping, employing groundnut leftovers, and creating soil ridges to prevent erosion enhance soil fertility and lessen the adverse environmental effects of chemical fertilizers [14].
Additionally, the use of groundnut products in various factories protects the environment from the effects of increased contamination from synthetic chemicals. For example, groundnut oil is used in the production of paint, varnish, lubricant oil, leather dressing, polish, insecticide, and cosmetics; in addition, groundnut sludge is used to make soap; in contrast, groundnut shell is used in the plastic, wallboard, cellulose, glue, and abrasive industries [20].
The majority of groundnuts are consumed in the internal markets of the nations that produce them; nevertheless, some import groundnuts despite producing more of them [45].
Because groundnuts are needed as a snack in North America and the European Union, as well as because they are a high-protein food in many sub-Saharan countries, farmers describe groundnut production as profitable and use the money they make to buy cereal grain for household consumption [1]. The groundnut market is stable internationally [46].
While groundnut and animal products have similar fat and energy content [17], Table 2 below demonstrates that groundnut, or peanut, contains more energy (567 kcal/100 g), protein (25.8 g/100 g), fat, mainly monounsaturated fatty acids (49.2 g/100 g), vitamins (niacin, folate), and minerals like copper and manganese [47,48].

In sub-Saharan African nations, smallholder farmers who cultivate groundnuts not only profit from the sale of their produce but also eat it at home, improving their children's nutritional needs [14]. Sub-Saharan African nations like Malawi, Zambia, Mozambique, Uganda, Senegal, Nigeria, and Sudan produce groundnuts for food in the form of raw, roasted, salted, boiled, and milled groundnut flour (served by combining it with leafy vegetables); they are also used to make peanut butter and oil; the groundnut cake, which is left over after pressing for oil, is used to make food or feed and is a crop that smallholder farmers can use to generate income [7]. In southern African nations, groundnuts are utilized to make weaning foods that go well with the high-energy maize crop [48].
In Northern Ghana, Kuli-kuli is made from the groundnut by-product of oil extraction, and groundnut flour is frequently used to flavor or season porridge [49]. One way to eat peanut butter is to spread it over bread and use it as a vegetable sauce [48]. A popular food item in the eastern region of Ethiopia is halawa, a groundnut cake [33].
Food and nutritional security initiatives in Sub-Saharan African (SSA) nations are being strengthened by the growing demand for groundnuts and their byproducts, which is opening the door for producers to earn more money and feed their families wholesome food [46]. While some African groundnut farmers utilize the money they earn to purchase agricultural inputs, others sell their groundnuts and use the proceeds to purchase other crops and foods [14]. A society's health and well-being are improved by increased food and nutritional security, which in turn boosts agricultural output and productivity [46]. Although the price at harvest is lower than during the lean season, farmers sell their produce after harvest since the money is essential for home needs and for their children's school fees [11].
The livelihood of small-scale, subsistence African farmers can be improved by adding value to groundnuts, which will increase their acceptance in domestic and foreign markets [43]. Value-added goods like peanut butter, cooking oil, snacks, and animal feed can be made from groundnuts [13].
As animal feed, groundnut haulm has a greater protein content (11–17%) than cereal grain hay (2–8%), which can help fatten livestock and increase household income to maintain food security [43]. Protein is obtained from groundnut deoiled cake, which is produced when the groundnut is pressed for oil [2].
Groundnuts also include coenzymes like CoQ10 and antioxidants [48]. Groundnuts are preferred for nutrition enhancement due to their greater fiber content, higher unsaturated fat content, and plant-based protein [48]. Groundnuts are a "poor man's protein source," according to Settaluri et al. [52], but they are also a good source of vital amino acids, mono- and polyunsaturated fatty acids, vitamin B and vitamin E, minerals like calcium, phosphorus, potassium, iron, zinc, copper, and selenium, and less sodium. In addition to being rich in protein, vitamin E, niacin, folate, copper, and manganese, groundnuts also contain the antioxidants p-coumaric acid and resveratrol [53]. Additionally, eating

groundnuts is linked to decreased cardiovascular disease by decreasing low-density lipoprotein (LDL), lowering the risk of colon cancer [53], blood pressure, diabetes, Alzheimer's disease, gallstone development, and obesity [48, 52]. According to Bonku & Yu [54], eating groundnuts lowers the risk of cardiovascular disease and gallstones in both men and women, but it lowers the risk of diabetes in men only. Additionally, a groundnut diet is said to lower the risk of inflammation, cancer, and hypertension. Additionally, ready-to-use therapeutic foods (RTUF) with a protein level of roughly 26% and a groundnut oil content of roughly 50% are preferred for the rehabilitation of children who are extremely malnourished. Additionally, hospitals and school feeding programs are including groundnuts in their regular meal plans [43]. Only one-third of groundnuts are used for food; the other two-thirds are used to extract their oil [49]. Higher-quality groundnuts should be used in a variety of recipes to familiarize people from around the world with the cuisine.

Conclusion

Indicators of groundnut quality loss include noticeable alterations in color and flavor, insect infestation, mold growth, punctured, shriveled, and damaged pods, high-moisture pods and/or kernels, and increased amounts of non-seed foreign matter combined with the groundnut. The causes of groundnut quantitative losses include insect pest assault, microbial bio-deterioration, decay, contamination, and spillage during various supply chain operations. Quantitative food losses also include groundnut kernels that are removed from the supply chain because their aflatoxin level is higher than permitted and they are not eaten by humans since they pose health hazards. In African nations, post-harvest groundnut losses range from 8.9% in Ghana to 31% in Uganda. For small-holder farmers in sub-Saharan African nations, the increased labor intensity of the groundnut supply chain is a constraint. Pod stripping, shelling, and on-farm and warehouse storage of groundnuts in the supply chain all result in increased post-harvest losses in terms of both quality and quantity. Therefore, various lifting, pod stripping, pod shelling, and kernel sorting technologies that are more effective, less expensive, and locally accessible should be introduced and made available to Africa's smallholder groundnut farmers in order to reduce losses. Groundnut kernels and/or pods of lower quality should be completely removed from the supply chain and utilized as substitute raw materials in industrial applications that are not related to food or feed. Aflatoxin-resistant groundnut varieties should be made available to groundnut producers, and proper agricultural techniques should be followed both before and after harvest, given the tremendous potential of groundnuts to improve soil fertility and fight protein and energy deficiencies. Furthermore, there should be a broad public awareness campaign about aflatoxin toxicity and mitigating strategies.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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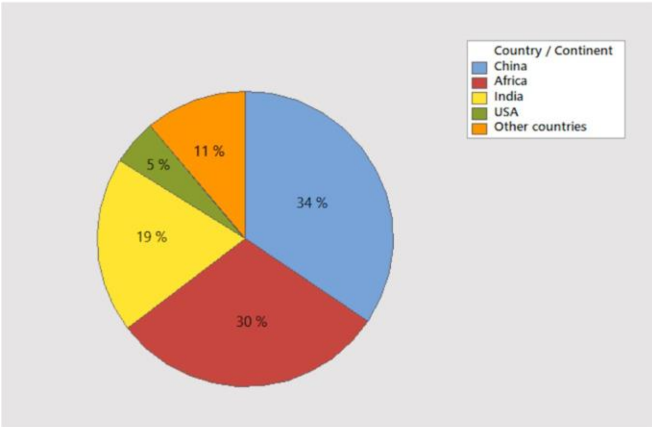

Figure 1. World groundnut production in 2021 [5].

Table 2

Nutritional value of groundnut in comparison with teff, maize, wheat, sorghum, and rice per 100 g (Mupunga et al. [48]; Baye [50]; ᴪGirmay et al. [51]).

Energy & Nutrients	Groundnut	Teff	Maize	Wheat	Sorghum	Rice
Energy (kcal)	567	357	375	370	359	357
Carbohydrate (%)	16.13	73	72	63	71	64
Crude protein (%)	25.80	11	8–11	8.3	11.7	7.3
Crude fat (%)	49.24	2.5	4.9	3.9	2	2.2
Crude fiber (%)	8.5	3.0	1.69ᴪ	0.6	2	0.6–1.0
Iron (%)	4.58	11.5 to >150 (red & mixed teff)	3.6–4.8	3.5–4.1	3.7	1.5
Zinc (%)	3.27	2.3–6.7 (mixed teff)	2.6–4.6	1.4–1.7	1.7	2.2
Calcium (mg)	92	78.8–147 (mixed teff)	16	5.0–5.8	15.2–39.5	23
Copper (mg)	1.144	1.6 (mixed teff)	1.3	0.41	0.23	0.16