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Review article

The Ethiopian snack food ('Kolo'): Existing knowledge and research directions on processing practices, quality and consumption

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A B S T R A C T

'Kolo' is an Ethiopian well-roasted and dehulled barely snack food eaten alone or mixed with other roasted grains with a relatively long shelf life. It is an ancient and staple Ethiopian snack food that is being introduced around the globe. Traditionally, Kolo has been prepared by Ethiopian mothers. However, there is a scarcity of documented information about the nutritional profile, consumption status and effect of processing conditions on quality of Kolo. Therefore, the aim of this review is to access the indigenous processing practices, consumption status and the effect of processing conditions in quality of Kolo. The review discussed in detail the raw materials, processing steps, nutritional status, anti-nutritional factors, digestability and functional properties of Kolo from publications from the last thirty years. Due to the high temperature processing condition, the presence of acrylamide is highly likely and this may affect the safety of Kolo. The anti-nutritional factors in Kolo may affect the nutritional quality of Kolo due to the inaccessibility of nutrients. This information could have a significant contribution for future researchers, policy makers, society and producers. In conclusion, there is a need to get more tangible information about the quality and safety of Kolo through well designed scientific research to safeguard the wellbeing of the society.

1. Introduction

Consumers enjoy and use snack foods as ready-to-eat breakfasts prepared from cereals, which constitute a varied and ever-expanding category of food products [1]. Similarly, in India, roasted barely and legumes are used as snacks and to prepare other foods [1]. Different snack foods are prepared and consumed in Ethiopia, such as popcorn [2], roasted maize [3], extruded products [1], and Kolo [4].

Kolo is a dehulled, well-roasted barely grain, eaten as a snack or combined with other roasted seeds such as roasted chickpea, soy bean, sunflower head, and ground nut [1,5]. If it is properly packed, the shelf life of Kolo is relatively long; it can stay for about a year or more without any deterioration [2,3]. Mostly, Kolo prepared from roasted, barely mixed with ground nuts is common in the market and is selected by consumers. Due to their high nutritional content, delicious flavor, and affordability, especially in poor nations, peanuts are a popular protein, fat and energy-rich legume that are consumed all over the world [6].

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To increase aroma, color, and taste, Kolo producers add different ingredients like pepper powder, salt, and oil, followed by mixing and air ventilation before it goes to packaging. As a snack food, Kolo is highly expected to be a good source of energy. Since Kolo is prepared from cereals and legumes, its nutritional profile may be high. Few research studies have indicated that Kolo has numerous health benefits, including sources of energy due to the composition of barely and other legumes [7], decreasing blood cholesterol, controlling the glycemic index, and antioxidant activity due to its high fiber content [4]. It also has also, iron and zinc (up to 60 ppm) than other major cereals, a higher vitamin A and E content, and approximately 3.3 calories per gram of energy [8]. It is also eaten by people with gastritis problems [9]. However, there is little information about the actual nutritional profile of Kolo except for micronutrients [8]. The effect of processing conditions, especially during roasting, may affect the nutritional composition of Kolo may affect. Mostly vitamins, and there could be structural changes in protein in Kolo, even though there is little documented information.

The consumption of Kolo has been increasing in the country and out of the country due to shared culture; therefore, it is being introduced in other countries through people migrant to other countries, but there is little documentation that shows the statistics of Kolo consumers across the globe.

Roasting at high temperatures for a long time may affect the safety of the Kolo due to the acrylamide formation and the safety of the product. The formation of acrylamide in Kolo is expected to be high due to a reaction of free amino acids (asparagine) with reducing sugars during the roasting of barely grain and legumes [9]. Unroasted foods are free from acrylamide, but depending on the temperature and processing duration, the formation of acrylamide occurs when the roasting temperature is above 120 °C [7]. Beside the acrylamide microbiological aspects of Kolo, another health threat and mostly the safety of Kolo shall be seen by associating with mold contamination and its metabolites, or mycotoxins. Ochratoxin A is expected in barely grain, and this mycotoxin is known to be carcinogenic and mutagenic and has been demonstrated to be nephrotoxic and hepatotoxic [8]. Similarly, peanut, which is a raw material for Kolo, is another source of microbiological hazards. Therefore, mold developments and their metabolites in barely and legumes these affect the safety of Kolo [7,10].

On the other hand, due to the presence of different anti-nutritive factors, the digestibility of Kolo is also affected, even though there is little scientific information. In reality, anti-nutritional factors decrease the accessibility of nutrients; therefore, people who consume Kolo frequently may not get important macro- and micronutrients from their meals due to the binding properties of anti-nutritional factors. This indicated that there has to be research directions on the reduction of anti-nutritional factors to mitigate the inaccessibility of nutrients through processing conditions such as soaking, roasting, and dulling and their combinations.

In addition, the consumption of Kolo has been increasing more than ever before. In the past, Kolo was used when there is different events such as marriage, birthdays, and funeral ceremonies were always observed in addition to national and religious holidays [11], but recently it has been used during many official meetings or while traveling [4]. University students have used it as a snack food when they are away from their parents. Therefore, it becomes a staple food and is consumed in all seasons [8]. All these findings show that Kolo may have a role in the economic and food security of the country [12]. This indicated that to assure the safety, quality, and digestibility of Kolo, the consumption status of Kolo shall be known.

However, there is a scarcity of documented information about the local processing practices, nutritional profile, and culture and consumption status of Kolo. Therefore, the aim of this review is to access the available information about the indigenous processing practices, consumption status, nutritional profile, and the role of processing conditions on the quality attributes of Kolo from publications from the last thirty years. This information could have a significant contribution for future researchers, policymakers, society, and the food processing industry.

2. Raw material and processing of Kolo

Kolo is produced from a variety of cereals and legumes. The main raw material for Kolo production is barley. Kolo made from maize is a common dish in rural areas where there is a high maize grain production. Grain legumes like peanuts, chickpeas, peas, and beans are rarely used to make Kolo. Mostly barely grain is used to make Kolo, either alone or in combination with other roasted grains mentioned above. In addition to grains and legumes, spices are added on Kolo to improve its texture, color, flavor and aroma. Examples of these spices are pepper powders (also known as 'Berberie duket'), salt, oil, and honey and sometimes butter.

2.1. Types of barely used for Kolo processing

Like other indigenous foods, Kolo has been prepared by Ethiopian mothers. Of course, the preparation may not be the same everywhere in the country. There are different types of barely available in the Ethiopian market, but all types of barely are not used for Kolo preparation. Basically, the types of barely used for Kolo preparation depend on availability, cost, and yields. Due to these, different varieties of barely varieties are used, such as ***Teklie gebs***, ***Derg gebs***, ***Woremene***, ***Semeno***, ***Nech gebs***, ***Awura gebs***, ***Shegie gebs***, ***Shewa gebs***, ***Tikur gebs***, ***and Dinble nech gebs*** [13]. From different types of barley, '***Senefe gebese***' and 'Temeje gebse''are common and known by Kolo producers. Thus, the first and most important thing to prepare quality Kolo is the selection of appropriate types of barely. Due to different characteristics (thick size, black-grey color), ***Senefe gebese*** is selected than '**Temeje**' by the producers for the production of Kolo. In addition to this, ***Senefe gebese*** can be soaked with hot water to remove the husks and become strong enough during scouring and dehulling. Moreover, ***Senef gebs*** is not cracked and pops up like popcorn during roasting. Whereas, **Temeje** cannot be soaked in hot water since it is mechanically very weak; rather, spraying a small amount of water uniformly on the surface can remove the husks. In addition, unlike ***Senef gebs***, ***Temej gebs*** cracked and popped up during roasting.

2.1.1. Processing steps for production of Kolo

2.1.1.1. Cleaning. The first step in Kolo preparation is the cleaning of barley, which is a key process for preparing good-quality Kolo. The immature, broken, non-barely grain; discolored, over and undersized and bad-smelling grains are removed, followed by winnowing to remove light and dust particles.

2.1.1.2. Scouring. The initial scouring by wooden mortar or pounder, locally called 'Mukecha' (similarly shown in Fig. 1F), takes place after cleaning and is used to remove awns. After scouring, the awns or chaffs are separated from the barley by winnowing. If the broken grains and chaffs are not separated from the grain, they will burn easily during roasting and affect the quality of the Kolo.

2.1.1.3. Washing. Washing is an important unit operation to remove soluble dirt materials and some undesirable microorganisms from the surface of the grains. In addition, it is essential to reduce some anti-nutritional components of the grain. β-Glucan is the main anti-nutritional factor found in barely grain [14–16]. It is a non-starch polysaccharide found on the walls of endosperm and aleurone cells of barley and constitutes 2–11% of the total kernel carbohydrates but usually ranges between 4 and 7% [16]. This kind of anti-nutritional factor is reduced by frequently washing the grain. Furthermore, washing is important to increase color and keep the grain from breaking.

2.1.1.4. Soaking. After washing, the barely is soaked with hot water for a few minutes (Fig. 1B), or sometimes semi-boiled barely is used. The purpose of soaking is to loosen the attachment between the lemma and the aleurone layer and to toughen the lemma during dehulling or scouring. Immediately, the soaked or boiled barely is filtered using a sieve, which is traditionally called 'Manteftef'. Besides, soaking is used to remove the soluble nonstarch polysaccharides (β-glucan and pentose). The degree of soaking and the removal of β-glucan and pentose depend on the amount of water used and the soaking time [15]. Reference [16] find out that the longer the soaking time that leads to a reduction in the percentage of tannin (58, 61 and 65%) and phytic acid (64, 69 and 71%) at 2, 4, and 6 h, respectively. However, the temperature of the water for soaking depends on the types of anti-nutritional factors being reduced. For example, soaking or steeping with hot water is appropriate for enzyme inhibitors such as protease inhibitors and lectins [17].

2.1.1.5. Drying. Commonly, direct sun drying is applied to reduce the moisture content of the soaked barely grain (Fig. 1C). This unit operation is also important to decrease the energy consumption needed during roasting.

2.1.1.6. Roasting. For roasting, the metal pan or clay pan should be heated up first, and then a small amount of soaked and dried barely is added and continuously stirred (Fig. 1D). Roasting is done till the color is changed to brown and stops the popping up sound. The roasted barely from a different batch are not stored in the same container to avoid excessive heat and getting cooled separately. Finally, roasted and cooled product at different batches can be mixed together for dehulling.

2.1.1.7. Dehulling. Dehulling is done slightly using a traditional wood-made pounder (Fig. 1F). This unit operation is used to remove the bran (lemma) and remaining awns (chaffs) from roasted barely. During dehulling, if the bran and the remaining chaffs are not

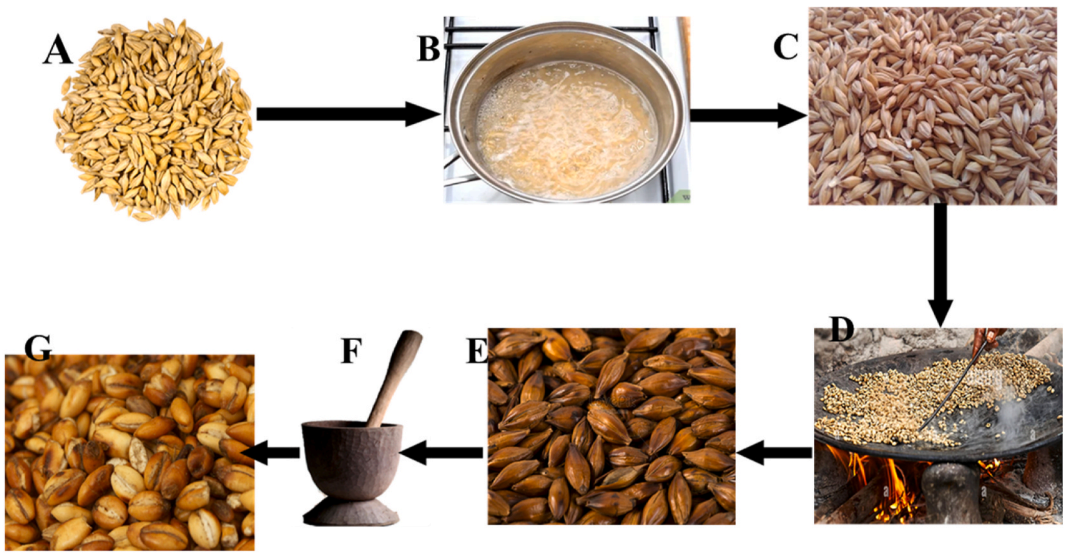

Fig. 1. Process description: (A) Raw Barley, (B) Soaking, (C) Sun drying, (D) Roasting, (E) Roasted Barley, (F) Dehulling using Wooden pounder, (G) Roasted and dehulled barley (Kolo).

completely removed, a second round of dehulling may take place.

2.1.1.8. Separation. After dehulling is completed, husks, chaffs, and broken barley are removed by winnowing.

2.1.1.9. Mixing. Mixing with other roasted ingredients like sunflower heads, chickpeas, and groundnuts (Fig. 2A, B, C) is the final step to obtaining Kolo. Here, salt, oil, pepper powder, honey, and butter can be mixed to improve the taste, color, aroma, flavor and overall palatability of Kolo. These palatability enhancers should be mixed together separately in a warm pan. Then all the mixtures are mixed together and rubbed extensively till the colors of the mixture become uniform. This is the final Kolo product (Fig. 2D). Then the Kolo should be dried and air-ventilated before packaging. Drying and air ventilation are very important since it has some heat and moisture, which can lead to a bad smell and mold growth after packaging.

Kolo can be served in different occasions and ceremonies. It can be served in coffee ceremony (Fig. 2E) as a snack, in beer garden (Fig. 2F), with traditional beer (tella) (Fig. 2G)during traditional gatherings or single households.

3. Nutritional aspects of Kolo

3.1. Nutritional content of Kolo

As indicated in Table 1 below, barely consists of both micro and macro nutrients, of which the primary components are carbohydrates, proteins, lipids, and minerals, along with a number of secondary metabolites such as vitamins and phenolic compounds [7, 18,19]. Barley grain consists of about 65–68% starch, 10–17% protein, 2–3% free lipids, 4–9% β-glucans, and 1.5–2.5% minerals, and total dietary fiber ranges from 11 to 34% containing soluble dietary fiber within 3–20% [4]. It may be difficult to put the actual composition of barely, the composition may be affected by the types of species, growing area, and fertilizer used [20].

Since Kolo is dominantly prepared from barely, it is highly likely that the nutritional profile of Kolo is related to the composition of barely. According to Ref. [9], barely has numerous health benefits, including sources of energy, decreasing blood cholesterol, controlling the glycemic index, and antioxidant activity due to its high fiber content. It is likely that Kolo may have similar benefits.

The nutritional value and the role of processing conditions on Kolo are not yet studied. The findings of [23] showed that the nutritional profile of food is improved when anti-nutritional components are reduced. Therefore, the presence of different anti-nutritional factors in raw materials during Kolo preparation would have a significant effect on the nutritional value. On the other hand, due to roasting, the nutritional composition of barely will be affected, especially vitamins, which will be lost due to the high roasting temperature and long time. Therefore, to improve the nutritional aspect of Kolo, scientific study is required.

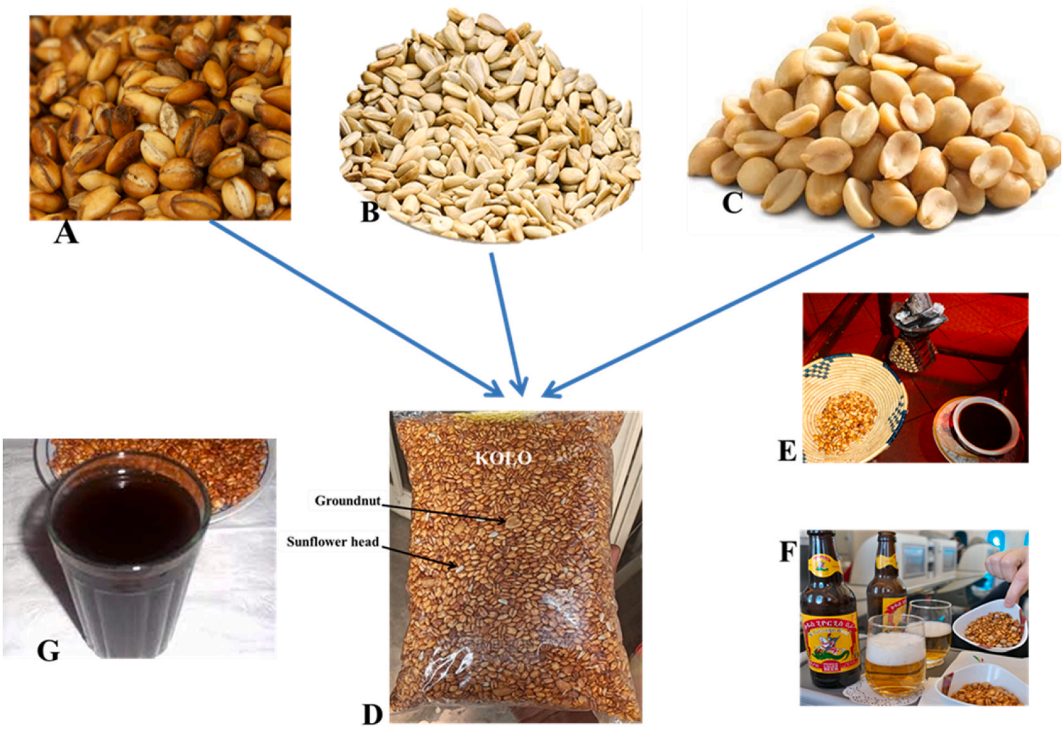

Fig. 2. Kolo mixing and servings: (A) Roasted and dehulled barley, (B) roasted sunflower seed, (C) Roasted and dehulled peanut, (D) Final mixed and packed barely Kolo, (E) Serving Kolo in coffee ceremony, (F) Serving Kolo with beer and (G) Serving Kolo with traditional beer (Tella).

Table 1
Macro and micro component composition of barely grain (%).

Carbohydrate (%)	Protein (%)	Fat (%)	Fiber (%)	Minerals (%)	Vitamins (%)	Phenolic (%)	References
–	10.0–20.0	–	14.8				[21]
78.0–83.0	7.0–25.0	3.1–3.6	–	2.5–3.1	0.9–3.2	0.1–0.5	[11]
77.2	9.9	1.2	15.6	–	–	–	[7]
65.0–68.0	10.0–17.0	2.0–3.0	11.0–34.0	–	–	–	[22]
80.0	11.5–14.2	4.7–6.8	–	1.8–2.4	–	–	[9]

3.2. Anti-nutritional factors in Kolo

Anti-nutrients are biomolecules that can reduce either utilization or absorption of nutrients when they are present in food along with nutrients. Anti-nutritional factors are substances that decrease the nutrient utilization and/or intake of plant-based food products used in human diets. On the other hand, it refers to a substance that is produced in natural food products by a species' normal metabolism as well as by various mechanisms (e.g., inactivation of certain nutrients, slowing down the digestive process, or metabolic utilization of feed). These have effects that are counterproductive to optimal nutrition [17,19,24,25]. Researchers have been debating the advantages of nutrition and the effects of anti-nutritional factors for a long time. Some scholars agreed that anti-nutrients have a beneficial effect on health when consumed at low concentrations. In addition, if anti-nutrients are consumed in an adequate amount, they may act as a useful natural drug to ameliorate human health [17,24–26]. On the other hand, studies indicated that there is an adverse effect of anti-nutritional factors on human health. Anti-nutrients are regarded as toxic secondary metabolites of plants that have a negative influence on nutrition and health since their frequent use might obstruct normal development, reproduction, and health. Because of this, anti-nutritional components are currently considered to be dangerous and toxic secondary metabolites of plants [24].

If the food is not utilized and absorbed to the required level, it is difficult to get sufficient energy. This is because of the inaccessibility of nutrients due to anti-nutritional factors. Due to its high fibre content, Kolo is likely rich in anti-nutritional components, which means it might not offer the anticipated energy. As a result, an issue like childhood stunting will arise from nutritional inaccessibility. This might be a significant problem, particularly in Ethiopia, where Kolo is frequently used and food insecurity is widespread. However, certain methods for lowering anti-nutritional factors during Kolo processing are employed. Understanding the kind and nature of anti-national factors is also crucial for enhancing the nutritional value of a particular food. It is therefore important to investigate the various kinds of anti-nutritional factors and their mitigating mechanisms.

3.2.1. Types of anti-nutritional factors in Kolo

Different anti-nutritional factors are found in plant-based foods like Kolo, but the level and amount will vary from one food source to the other. Based on their chemical and physical characteristics, anti-nutritional factors in grains and legumes can be categorized into a number of groups, such as non-protein amino acids, quinolizidine alkaloids, cyanogenic glycosides, pyrimidine glycosides, isoflavones, tannins, oligosaccharides, saponins, lectins, or protease inhibitors [24]. On the other hand, ant-nutritional factors are also divided into two main categories: proteins (protein inhibitors and lectins) and phatic acids and tannins [27]. Furthermore, anti-national factors can also be categorized as heat-stable and labile. These include goitrogens, lectins, protease inhibitors, amylase inhibitors, antivitamin factors, tannins, phytic acid, gossypol, and saponins [26]. Hundreds of review papers have been reported about anti-nutritional factors found in plant-based foods. But only a few reported the common anti-nutritional factors available in barley, such as tannin and phytate [28].

β-Glucans are the main anti-nutritional factors for barely grain [14–16]. β-Glucan is a non-starch polysaccharide found in the walls of endosperm and aleurone cells of barley and constitutes 2–11% of the total kernel carbohydrates but usually ranges between 4 and 7% [16]. All these findings indicated that a food like Kolo prepared from cereals and legumes may have a high amount of anti-nutritional factors. This affects the human health of those who consume Kolo frequently. Therefore, to mitigate the above problem, the reduction of anti-nutritional factors during Kolo production is important.

3.2.2. Reduction of anti-nutritional factors in Kolo

It is crucial to understand how to reduce anti-nutritional factors once they've been identified. Several approaches are employed to lower anti-nutritional factors, such as: soaking, dehulling, fermentation, germination, and their combinations. However, one unit operation is insufficient to decrease all anti-nutritional factors [28] Conclude that phytic acid, tannins, and lecitin activity significantly decreased with the combined effect of soaking followed by cooking treatments. In addition, soaking mostly removes β-glucan and pentose, and the degree of soaking depends on the amount of water [15]. Kolo may contain the aforementioned anti-nutritional factors; however, the levels could be reduced upon soaking and roasting. However, there is a lack of documented information and published research that has been conducted to study the effect of soaking and roasting on anti-nutritional factors in Kolo.

The reduction level of anti-nutritional factors could also depend on the soaking time and the temperature. For example, soaking or steeping with hot water is appropriate for enzyme inhibitors such as protease inhibitors and lectins [17]. However, the role of soaking time in reducing the mentioned anti-nutritional factors during the processing of Kolo has not been studied yet.

[16] reported that the longer the soaking time, the higher the reduction percentage of tannin (58, 61, 65%) and phytic acid (64, 69.71%) obtained at 2, 4, and 6 h, respectively. On the other side, those anti-nutritional factors cannot be removed by the conventional

heating process as heating time increases [29]. A research work reported by Ref. [27] showed that cooking was an effective method to reduce enzyme-based anti-nutritional factors, but phytic and tannin levels were not decreased, but rather phytic acid was increased. Here, cooking is not applied for Kolo preparation; rather, roasting is used. Similarly, it is highly expected that heat-sensitive enzyme-based anti-nutritional factors will be reduced during roasting. But it is difficult to judge whether phytic and tannin are reduced or not during roasting. Thus, in order to address these knowledge gaps, a well-designed study is required.

Recently, reductions of anti-nutritional factors in different legumes have been reported to improve the accessibility and absorption of nutrients under different processing conditions. The anti-nutritional components, especially those that are heat-sensitive, are reduced through the thermal processing of Mucuna seeds and consequently, the nutrient accessibility of protein and starch has improved proteins with some structural and functional quality changes [30]. Pulses such as lentils have undergone varying degrees of reduction in anti-nutrient levels through the use of emerging techniques like dielectric heating, extrusion, γ-irradiation, ultrasound, and high hydrostatic pressure [31]. Generally, mitigation of anti-nutritional factors in grains and legumes improves food safety concerns [11].

3.3. Digestibility of Kolo

The level of digestibility of food indicates the degree of accessibility and absorbability of nutrients that leads a consumer to get sufficient energy. Even though the level of protein, lipid, and carbohydrate in Kolo is expected to be high, and Kolo consumers could get high level of energy. However, it is difficult to state that the food is highly digestible and gives consumers a lot of energy because it depends on how efficiently it is absorbed and/or digested [32]. For this reason, one of the most important food quality factors is digestibility. As a result, the energy derived from Kolo has a strong correlation with nutrient accessibility. Kolo's digestibility may be primarily influenced by the existence of anti-nutritional factors. Therefore, a detail study on Kolo's digestibility is required to mitigate health issues that could occur due to nutrient deficiencies.

Researchers agreed that low nutrition is directly related to low digestibility, which is also associated with a lack of pretreatments of anti-nutritional factors [27]. The main activity of anti-nutritional factors is to inhibit the accessibility and absorbability of food by making cross-linkage with bivalents and, finally, accumulation without absorption. Therefore, the digestibility of a Kolo can be improved with the reduction of anti-nutritional factors with some pretreatments [27,33].

The level of protein, starch, and mineral accessibility is one of the common parameters that indicate the digestibility of a food. The quality of food depends not only on the composition but also highly on the degree of digestibility [34].

Different reports agreed that the aim of food processing is to promote overall digestibility by influencing these external and internal components of food [17,26,27,29,33,34]. Therefore, the processing of Kolo, such as soaking, dehulling, and roasting, would improve its digestibility. Therefore, food preparation methods such as germination, fermentation, roasting, and soaking may also increase the bioavailability of nutrients in food [35]. According to the previous studies, black soybean's phytic acid and tannin contents decreased significantly during processing treatments. Phytic acid decreased to the extent of 34.04, 51.06, and 13.47%, and tannin contents decreased to 47.22, 75, and 38.89% after germination, fermentation, and roasting processes, respectively. This suggests that better digestibility might be gained with an increase in bioavailability of nutrients and a reduction in anti-nutritional factors in Kolo during roasting. There is also a report that shows that the reduction of anti-nutritional factors in legumes can increase the accessibility of nutrients due to their high digestibility [30,11].

4. Functional properties of Kolo

The functional properties of roasted grains, including Ethiopian Kolo, are not well explored by the scientific community. Functional properties of food are important characteristics to convince and satisfy the consumer [36]. Therefore, the functional properties of Kolo, like texture, crispiness, color and moisture-absorbing (hygroscopic) properties, in relation to the processing conditions should be studied and documented. Recently, consumer awareness of their meal has increased, Kolo is not an exception, and the functional properties of Kolo need to be known by the consumer.

5. Safety of Kolo

Every food has to be safe for consumption. However, for roasted foods like Kolo, acrylamide formation is expected. The formation of acrylamide is high due to a reaction of free amino acids (asparagine) with reducing sugars during the roasting of barely grain [9]. In addition, acrylamide can be formed due to lipid oxidation while roasting. According to studies, acrylamide is not present in raw foods but, depending on the temperature and processing duration, can be present in foods that have been processed at temperatures higher than 120 °C [7]. Acrylamide is reported as probable cancer caused compound and affect the health of the consumer if it is consumed frequently or beyond the allowed limit. Studies indicated that tolerable daily intakes of acrylamide are assessed to be 40 g/kg bw/day for neurotoxicity and 2.6 g/kg bw/day for carcinogenic effects [37]. However, in roasted barley and other heat-processed foods, the acrylamide level is expected to be high [38] Reported that the Keribo sample made from deeply roasted un-malted barley had a significantly high acrylamide concentration (3.44 g/kg). This indicates that the acrylamide level of Kolo is probably higher than the allowable limit due to its roasting operation, and this could affect the health of large number of consumers. That is why safety is a big concern and remains a global challenge, especially in developing countries for their traditional foods like Ethiopian Kolo. Kolo should be safe and free from harmful chemicals that are responsible for chronic and acute diseases [39]. For roasted food products like Ethiopian Kolo, acrylamide is expected since the roasting temperature is relatively high (greater than 120 °C). Related findings also indicated that the average content of acrylamide is reported to be 0.24 mg/kg among 45 commercially available roasted barley grains for mugecha [12]. Besides, according to the previous author, the acrylamide concentrations of two commercially available roasted barley grains were found to be 234 and 546 μg/kg. This indicated that Kolo will have the highest acrylamide formation with the reported values of 234–546 μg/kg. From this, it can be understood that the main cause of acrylamide formation is high temperatures. Roasting raised the amounts of acrylamide to their highest points at 322 μg/kg for kernels, 586 μg/kg for thin flakes, and 804 μg/kg for thick flakes when the roasting temperature was increased from 160 to 200 °C for 20 min. However, the acrylamide formation of roasted barely can be decreased as the roasting temperature increases from 140 to 240 °C, was found below 0.4 mg/kg [40]. At high roasting temperatures, which may be above 180 °C, acrylamide starts to degrade due to the development of melanoidin; therefore, if Kolo is roasted at high temperatures, the color is still dark, and the acrylamide level will be the lowest [12]. Generally, during heat treatment of grains like barley, different reactions could be developed, such as millard and hydroxyl-methyl furfural, which are responsible for the desirable color and flavor change of roasted grains [41]. On the other hand, during heat treatment, toxic, carcinogenic, and neurogenic compounds like acrylamide are developed due to the pre-cursor of the Millard reaction [4].

5.1. Factors responsible for acrylamide formation

Acrylamide is a process contaminant that affect human health, and it forms when free asparagine is reacted with reducing sugars at high temperatures [23]. Studies demonstrated that raw foods are free of acrylamide, whereas processed foods at temperatures above 120 °C or higher contain varying proportions (concentrations) of acrylamide depending on the processing temperature and time. The amount of acrylamide content is different from product to product [42]. The severe heat treatments during roasting and the high starch content of barley could be favorable conditions for the formation of acrylamide in Kolo, similar to the observation of [38] for roasted barley that was used in production of Keribo.

High quantities of acrylamide are found in food products made from plant sources, such as cereal grains, due to natural precursors (reducing sugars and asparagine) [23] (. Studies indicated that acrylamide could also be formed from acrolein in fatty foods when asparagine is free; acrolein provides its carbonyl group, which favors its conversion into acrylamide in considerable amounts [43]. There has been a tremendous amount of research on acrylamide levels in foods; however, little research has been conducted specifically on Ethiopian traditional foods, with the exception of a published work by Refs. [23,38]. Their research focused on the presence of acrylamide in Keribo (a traditional fermented beverage from Ethiopia), coffee powder, potato chips, and French fries in Addis Ababa, Ethiopia, respectively. As a result, a study regarding the acrylamide content of Kolo and potential mitigation mechanisms for reducing its acrylamide levels should be conducted and documented.

5.2. Reduction mechanism of acrylamide

Therefore, to prevent and reduce the health risk to consumers due to acrylamide, it is better to consider the factors that facilitate this toxic compound, like roasting temperature, route of acrylamide formation, and Maillard reactions [12,44,13]. Many investigations have been carried out utilizing a variety of techniques, such as physical, chemical, and biological procedures, to restrict the production of acrylamide in cooked foods. Thus, all these alternative options can be used to mitigate the acrylamide level in roasted foods like Kolo. The most popular technological strategies for reducing acrylamide involve altering the raw materials (choosing plant varieties with low levels of acrylamide precursors), modifying the recipe or formulation (adding particular additives or ingredients that affect acrylamide formation), employing pre-treatments (such as blanching or soaking), and modifying the processing conditions (significantly varying the time, temperature, pressure, and pH of heat treatment) [14].

Asparagine treatment and the addition of glycine are two methods that have been employed to reduce the levels of acrylamide in different foods [45]. Physical processing techniques, such as blanching, soaking, and pH reduction, have an effect on the production of acrylamide [43]. Optimization of temperature and time can also reduce the formation of acrylamide levels [45]. However, there is no information about the acrylamide level of Kolo and its reduction strategy. Thus, efforts have to be made to understand the formation of the acrylamide level in Kolo and its associated factors. Furthermore, research should be done on how acrylamide can be reduced through optimization of roasting temperature and time by developing food modeling. Recently, predictive modeling has been applied to optimize roasting conditions to produce safe foods [15].

Therefore, the most important methods to mitigate acrylamide level during roasting of Kolo, predictive modeling has to be extensively used to produce safe Kolo. This could be important to ensure the safety of Kolo via validation of kinetic models by predicting the level of acrylamide formation [46].

Apart from acrylamide mold metabolites, aflatoxins such as Ochratoxin A in barely, and different mycotoxins in peanuts may affect the safety of Kolo. The most expected mycotoxins Kolo will be Ochratoxin A due to mold development in barley, this kind of mycotoxins will lead consumers for different health risks. As evidences indicated Ochratoxin A, is known to be carcinogenic and mutagenic and has been demonstrated to be nephrotoxic and hepatoxic [8]. Furthermore, Peanut, which is a raw material for Kolo, is another source of microbiological hazards due to the occurrence of aflatoxins and has different health risks for consumers [7,10]. Therefore, to mitigate microbiological risks in Kolo, the raw materials, such as barely and peanut, must meet criteria before being used as raw materials to produce Kolo.

5.3. Shelf life of Kolo

Kolo is a dry and shelf staple product due to relatively low water activity. But after roasting, mixing, and air ventilation, it has been packed with airtight plastic to protect it from moisture uptake since, as a dry product, it has a high hydroscopic nature and reabsorption will occur. So, the shelf life will be affected. So, smart packaging materials are very important to preserve the nutritional composition of Kolo.

6. Conclusion

Kolo is an Ethiopian traditional snack food mostly prepared from roasted barely (***Senfef Gebese***) and peanuts with different spices like salt, sugar, and pepper powder to increase its palatability. With the advancement of science and technology, consumer awareness about the quality of food has been changing, but the literature review done on the nutritional composition of Kolo is not sufficient, and this needs much work. In addition, different anti-nutritional factors are highly expected in Kolo, and this could affect its digestibility. When the digestibility of Kolo is low, it indicates that important nutrients are not accessible for absorption due to the binding nature of anti-nutritional factors. To improve the digestibility of Kolo, it is better to understand the types and nature of all possible anti-nutritional factors. As different literature reviews indicated, there is no single reduction mechanism for all anti-nutritional factors in grains and legumes. Therefore, the combined effect of soaking, scouring, roasting, and dehulling will improve digestibility. As a roasted product, the acrylamide formation of Kolo is another health threat and is being agreed upon as a safety issue. Findings indicated that the main cause of acrylamide formation is the reaction of free amino acids (asparagine) and reducing sugars (glucose and fructose) as part of the Millard reaction during roasting above 120 °C. Furthermore, mold contamination and their metabolites, such as aflatoxins in peanuts and ochratoxin in barely, are also another safety concern in Kolo.

7. Future out look

To improve the nutritional profile and digestibility of Kolo, it is important to work on the reduction of anti-nutritional factors through well-designed scientific studies. Acrylamide and mycotoxins are the biggest sources of health risks for consumers; therefore, there have to be efforts to minimize acrylamide formation due to high temperatures and prolonged roasting by using predictive modeling. To protect Kolo from mycotoxins, first the content of mycotoxins in Kolo must be done and if the result shows positive, then the prevalence of raw materials, mostly barely grain and peanuts, should be checked before the preparation of final products. Then develop methods to prevent Kolo from these toxic compounds.

8. Limitations of the work

The big challenge of this work is getting sufficient literature reviews on nutritional profiles, types, and amounts of anti-nutritional factors and their effects on the digestibility of Kolo. Similarly, it was difficult to get the actual acrylamide and aflatoxins levels in Kolo.

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Mekuannt Alefe: Writing – review & editing, Writing – original draft, Conceptualization. **Biresaw Demelash Abera:** Writing – review & editing, Writing – original draft, Conceptualization. **Mulugeta Admasu Delel:** Writing – review & editing, Writing – original draft, Conceptualization.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Biresaw Demelash reports nothing was provided by Bahir Dar Institute of Technology. Biresaw Demelash Abera reports a relationship with Bahir Dar Institute of Technology that includes: employment. Biresaw Demelash Abera has patent pending to NONE. M.A.A, B.D.A, M. A. D. There is no conflict of interest.

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