Journal of
Food Chemistry & Nanotechnology

https://doi.org/10.17756/jfcn.2023-159

Review Article

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Effect of Nixtamalization on the Nutritional, Anti-nutritional, Functional, Physicochemical and Mineral Properties of Maize (*Zea mays*) Tortillas

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Received: September 26, 2023
Accepted: October 15, 2023
Published: October 19, 2023

Citation: Hassan SM, Forsido SF, Tola YB, Bikila AM, Ahmed Z. 2023. Effect of Nixtamalization on the Nutritional, Anti-nutritional, Functional, Physicochemical and Mineral Properties of Maize (*Zea mays*) Tortillas. *J Food Chem Nanotechnol* 9(3): 132-140.

Abstract

The use of maize (*Zea mays*) in the developing world necessitates research into innovative processing techniques to streamline manufacturing and familiarize consumers with a wide range of food products based on maize. This study aimed to evaluate the effect nixtamalization on the nutritional, anti-nutritional, functional, physicochemical, and mineral properties of maize tortillas to better understand the nixtamalization settings. The nutritional contents and their availability may be impacted by the compositional characteristics of maize and local processing methods; for instance, during traditional food preparations, the pericarp is sieved out as unwanted material, which causes the loss of many nutrients present in the maize kernel structures. Nixtamalization is a common method that improves the nutritional contents of maize-based products and helps to create certain food varieties. In conclusion, the physicochemical, functional, mineral, and sensory qualities of Nixtamalized Quality Protein Maize (QPM) tortillas enhanced with soybean flour were enhanced by the cooking duration, steeping time, and lime concentration, enabling their acceptance by the consumer panelists.

Keywords

Functional, Nixtamalization, Physicochemical, Sensory properties

Introduction

Background

The predominant cereal grain consumed by significant portions of the rural and urban populations in Central America and Mexico is maize [1]. The crop provides substantial levels of macro- and micro-nutrients, encouraging the food industry to manufacture various products using maize as their primary ingredient [2]. Each African nation has its own unique maize local processing techniques, food items, and eating habits [3]. Maize is a significant and strategic grain for Ethiopian farmers' food security and way of life. It is grown on 2.13 million hectares and produces 8.4 million tons annually, or 39.44 quintals per hectare [4]. In Ethiopia, each person consumes roughly 60 kilograms of maize per year [5]. The nutritional contents and their availability may be impacted by the compositional characteristics of maize and local processing methods. For example, during traditional food preparations, the pericarp is sieved out as unwanted material, which causes the loss of many nutrients present in the maize kernel structures [6]. However, nixtamalization is a common method that improves the nutrient contents of maize, and it might further develop other certain food types through maize processing [7]. The procedure results in considerable physicochemical changes in the pericarp, germ, and endosperm as a result of the lime concentration (calcium hydroxide) and water dispersion into the maize grain's beneficial nutritional and sensory qualities [8]. Due to the nixtamalization process tortillas have higher nutrient contents, easier to digest, and have a lower anti-nutrient composition.[9] It is also consumed as a staple grain in significant maize-producing regions including western, southwestern, central, and eastern Ethiopia. Tortillas are always flat and round despite coming in a variety of sizes, thicknesses, and textures because they are constructed of maize that has been cooked with calcium hydroxide [10]. It is an unfermented flat maize bread with a variety of colors based on the maize flour source, and it's soft, flexible, and easy to roll. With 157 grams consumed daily per person in Mexico, tortillas are a vital part of the country's diet [11]. Thus, using QPM through the process of nixtamalization may aid in nutrient availability, boost protein quality with less nutritional loss, and decrease anti-nutrients. QPM and soybean products are included in items used for the prevention or treatment of malnourishment because cereal-legume blends have a high protein content and serve as a natural staple diet with a protein supplement [12]. However, there is little information on how different processing techniques affect the physicochemical, functional, mineral, and sensory qualities of cereal and legume blends, which may improve the nutritional value of the finished product. Therefore, this review aims to address the benefits of nixtamalization process to enhance the nutritional benefits of maize based staple food system.

Literature Review

Maize grains

Background informations

One of the most significant cereal crops worldwide is maize. It is the highest cereal crop in production and productivity compared to other cereals. After rice and wheat, maize is the third-most significant cereal and staple grain for human consumption [13]. In Sub-Saharan Africa, maize makes up around 40% of all grain production and more than 80% of all maize consumption [14]. It provides a total calorie intake of about a minimum of 30% calories to the population living in Sub-Saharan Africa. It is a staple food in African countries with regions where intake consumption ranges from 52 to 450 g/person/day, while Latin American areas consume 50 to 267 g/person/day [6]. Its kernels are like the other seeds; they are the storage plant organs, and the essential components of the plants contain growth and reproduction [15]. Moreover, many of these elements in the kernels, including protein, starch, and other micronutrients, are also similarly required for human health [15]. Maize-dependent consumption can lead to protein deficiency due to low lysine and tryptophan; these essential amino acids made the consumption of maize protein less critical and led to a significant problem in some rural areas of Mexico and Central America [16]. Because maize's primary protein component contains fewer of the important amino acids' lysine and tryptophan than other sources of protein, maize proteins are of lower quality [16]. QPM has, however, recently become more popular due to its higher levels of the essential amino acids' lysine and tryptophan when compared to common maize. These higher levels are important for both the quality of the protein and for human health [16].

Production of maize in Sub-Sahara Africa and Ethiopia

According to Mesfin and Shimelis [17], maize is the most adapted food crop in both the world and Africa, thriving under a variety of environmental circumstances and farming practices. In Africa, maize is a common food crop farmed by small-scale farmers, notably in the majority of Sub-Saharan nations [18]. With an estimated 200 million hectares of farmed land, maize covers more than 33 million hectares in Sub-Saharan Africa. An estimated 208 million people depend on maize for economic well-being and food security in these countries. In developing countries, maize demand is expected to double by 2050 and continue with the highest global production [18]. Since its introduction to Ethiopia during the 1600s and 1700s, maize has been showing an increasing trend of production, productivity, and diversity of ecological coverage. It is grown in various agroecological zones in Ethiopia and grows at altitudes ranging from 500 to 2400 m above sea level [19]. Of all the cereal crops grown in Ethiopia, maize ranks first in terms of overall production and second in terms of area sown [20]. The total annual grown maize has an area of 2.13 million hectares, followed by the entire production and productivity of maize which is about 8.4 million tons with approximately 39.44 quintals per hectare, respectively [4]. Moreover, most of the Ethiopian population uses maize as a source of dietary carbohydrates because maize is available in broader areas and has a wider range of uses. In Ethiopia, the consumption of maize is essential using different ways like injera, porridge, bread (Dabo), maize flatbread (Kitta), and boiled whole maize (Nefro). It's also roasted (Qollo) or cooked as a vegetable at the green stage [21]. Ethiopians consume more than 15% of their daily caloric intake from maize, which accounts for nearly one-third of the country's overall caloric consumption [22].

Uses and utilization of maize

Maize is used multi-purposely as food, fodder, feed, and seed, it's also a source of industrial primary raw material products, such as starch, protein, oil, food, alcoholic beverages, cosmetics, biofuel, sweeteners, etc. The immediate use of maize in the world is for feed for about 64%, human food for 16%, starch and beverage as industrial beverage products for 19%, and about 1% for seed [13]. Maize is usually prepared and consumed in various forms that have different ways of eating from country to country or region to region and can be different from one to another ethnic group. When cooked, roasted, fried, milled, or rushed, maize is used as food and can be further prepared for various food items [23]. Recently, the urban and peri-urban areas had a higher demand for value-added maize products, indicating a need for nutritional supplementation and fortification. Besides, maize with a rich source of nutritional composition can be added to commercially exploited health foods with nutritive value making them available, convenient, and reasonable cost to vulnerable groups and other consumers [13].

Limitations of traditional maize processing methods

Many developing nations, including Ethiopia, still use the traditional processing method of beating cleaned maize grain with a wooden mortar and pestle [9]. In various parts of the nation, traditional processing equipment comes in a variety of forms. For many years, cereals and pulses were processed using outdated techniques, which made them suitable for time-consuming meal preparations. Women run traditional processing machinery, which is primarily in charge of handling domestic food. The milling service providers still use machinery to mill and decorticate grain into flour. The hard duty of traditional processing is typically assigned to women [9]. When phytate localizes in the outer aleurone layer of cereals, traditional processing can remove the bran and/or germ, which lowers the phytate content of the cereals [24]. Additionally, whereas the mineral levels and several vitamins of these milled grains are simultaneously decreased, the bioavailability of iron, calcium, and zinc may be increased [25]. The procedures used in traditional food preparation are neither regulated nor standardized and rely on local expertise. It is difficult to guarantee consistent product quality to satisfy the demands of urban consumers since they do not measure the additional ingredients and do not regulate each unit's operation [25]. Additionally, conventional food preparations take a long time and labor-intensive.

Nixtamalization

The Aztec and Mayan civilizations invented and exploited the food processing technique known as nixtamalization, which is still in use today. Nixtamalization is a term derived from the Nahuatl language's indigenous "nixtli" root, which means lime or ashes, and "tamari," a maize dough, is an old treatment for maize grains that have been employed since 400 - 500 AC [26]. By taking into account people from Africa and Latin America, maize consumption ranges from 15% to 56%, even though it is an ancient practice in Mexico and other Latin American countries [26]. This process is not yet ingrained in the culture of the nations of Sub-Saharan Africa that produce and consume maize. Numerous essential foods, such as tortillas, tortilla chips, and snacks, are created using nixtamalization. When it comes to food preparation, grains that have undergone the nixtamalization process have a number of advantages over untreated grains. Nixtamalized maize is easier to mill, has more nutritional content, has better flavor and aroma, and has a lower likelihood of producing mycotoxins [27]. Improved protein quality, niacin availability, lysine availability [28], and higher calcium content [29] are all notable advantages of nixtamalization [30]. According to Bressani [31], the nixtamalization procedure raises the calcium content in QPM, and tortillas' protein quality is noticeably better than that of raw maize.

Nixtamalization process

The nixtamalization technique involves boiling maize in water with 1 - 5% lime (calcium hydroxide), which improves the protein quality, niacin availability, and calcium content of the grain while softening the pericarp of the seed [32]. Maize kernels are often cooked/boiled in water containing lime (calcium hydroxide) and then steeped for an entire night. The diffusion of water and calcium ions into the maize kernel during the alkaline treatment (cooking and steeping) of the corn kernel is one of the most important processes [33]. The increased pH and high cooking temperatures help grains moisten, soften in the endosperm, and release the pericarp during the nixtamalization process [33]. The surplus lime and the loosening pericarp are rinsed from the alkaline-cooked kernels (nixtamal) using water after draining the steeping liquid (nejayote).

Cooking time of the nixtamalization process

Milán-Carrillo et al. [34] investigated the nixtamalization conditions of cooking for 20 - 85 min, steeping for 8 - 16 h, and optimizing the alkaline solution with 3.3 - 6.7 g of $Ca(OH)_2$. Maize and foods containing maize have different cooking times and temperatures, ranging from 85 to 100 °C [35].

The lime concentration of the nixtamalization process

The cooking of lime ($Ca(OH)_2$) and the steeping process lead the grain to absorb water and calcium. Lime has a crucial function in the grain components' faster water absorption and distribution, as well as the modification of the pericarp fraction's outer layers to make it gummy and sticky [36]. According to Martinez-Bustos et al. [36], alkaline cooking most frequently uses lime concentrations of 1.0% based on corn weight to promote pericarp removal during cooking and steeping. Lime is used to reduce microbial activity, make it easier to remove the pericarp during cooking and steeping, and impact the texture, flavor, aroma, color, shelf life, and nutritional content of tortillas and snacks [31]. The amount of lime contained in nixtamalized products affects the product's texture, flavor, shelf life, and color [37]. According to Cuevas-Martinez et al. [37], consumers find tortillas to be unappealing if the lime content is insufficient to impart the typical alkaline flavor; conversely, if the lime concentration is excessive, the tortillas become astringent and are likewise disregarded.

Steeping time of the nixtamalization process

Currently, nixtamalization is a common method for processing maize throughout Mexico and Central America. The age-old method, which is still frequently used, entails heating maize grains in a lime solution, letting them soak for eight to sixteen hours, and then handwashing them to get rid of the pericarp [38]. The grains soften as a result of the water being distributed throughout them during steeping. Cooking changes the re-association of starch molecules during steeping and starch crystallinity, and it also develops the rheological characteristics of nixtamal dough [36].

Limitations of nixtamalized maize-based foods

More than one billion tons of maize are produced each year, making it the most frequently produced crop. Maize contains large amounts of calories, proteins, and micronutrients that are beneficial to people and animals. When Central American nations elaborated maize-based products through the nixtamalization process, maize became very important as an emerging industry [2]. As with tortillas, nixtamalized goods are regarded as fundamental staple foods. Tamales and tortilla chips are two examples of nixtamalized by-products that are useful for improving dietary intake. The demand for tortillas has expanded significantly across North America, Europe, and Asia [2]. The significance of this process is, however, subject to numerous restrictions. The primary issues include dry matter loss, which includes minerals and phytochemicals, high "nejayote" concentrations with a high pH of 9 - 12, and prolonged steeping times, which contain polluting residues

[2]. This proof indicates the nixtamalization process is mostly caused by the pericarp and germ tissue removal at the washing and cooking phases when the cooking water "nejayote" is removed [39]. Ineffective heat transmission, excessive water waste, and toxic effluents caused by the industrial scale's nejayote alkalinity are some of the constraints of the nixtamalization process [40]. Physical traits of the grain, like mechanical damage, low density, a thinner pericarp, and soft hardness, are some of the elements that enhance the loss of dry matter [41-44]. According to Sanchez-Reséndiz et al. [2], some of the nixtamalization conditions include extensive boiling times at a high temperature followed by long steeping times at a high temperature. According to numerous research, enriching soybean flours can reduce dry matter losses. It shows that consumers of mixes containing soy flour may enjoy goods with higher nutritional content than those manufactured entirely of nixtamalized maize flour [7].

Moisture content

For the best masa texture, however, there is typically a critical level of water absorption during the nixtamalization process of boiling with steeping for maize kernels. During the nixtamalization process, the moisture content of grain rises from 10 - 12% to 40 - 42%. According to Serna-Saldivar et al. [35], steeping the lime-cooked grains also raises their moisture content by 4 - 7% and more evenly distributes the water throughout the kernel.

Crude protein

In maize, protein is the second most prevalent proximate component after carbohydrates [44]. According to Tsegay et al. [45], the average protein content of the 37 maize varieties planted in Ethiopia ranged from 10.27 to 11.60, with a range of 7.48 to 11.60. The protein content of the MHQ138 variety is 11.60. As a result, it has the maximum protein content, whereas the Gibe-3 variety has the lowest protein content level at 7.48 g [45]. According to Almeida-Dominguez et al. [46], the protein content of nixtamalized maize flour ranged between 8.9 and 10.4%, or 6.7 - 11.6%. According to Kadir et al. [47], protein corn grits treatment with 0.5% lime concentration yields the greatest percentage of 9.4% after 30 min of boiling time, while the lowest rate of protein content is discovered in 1.5% after 60 min of boiling time, yielding 9.11%. Due to their nearly doubled percentages of lysine and tryptophan compared to regular maize, the QPM cultivars enhance the protein quality in diets based on maize. On the other hand, after traditional nixtamalization quality protein maize QPM (H-368C), Rojas-Molina et al. [48] showed 36 and 32% reductions in the total and reactive lysine, as well as 38.7% for tryptophan content.

Crude fat

In addition to carbohydrates and proteins, fat is the third nutritional component of maize [15]. With an average value of 4.90%, the fat content of Ethiopian maize types ranged from 4.01% to 5.99%. Ijabadeniyi and Adebolu [49] and Suryadi et al. [50] both looked at the fat content of maize in the ranges of 4.77% to 5.0% and 2.48% to 4.80%, respectively. According to studies on the nixtamalization of maize, the rate of fat damage varies depending on the processing time and temperature; the higher the temperature, the more damage to the fat content will occur. According to Pflugfelder et al. [51], the nixtamalization of grains results in a 20% loss in lipid content. Nixtamalization lowers the lipid content of QPM from 6.1 to 5.0%, according to Milán-Carrillo et al. [34]. The loss of pericarp and germ tissues during cooking and washing lowers the lipid content [44]. In comparison to controls and other treatments, the treatment using 1.5% lime concentration and a 60-minute boiling time had a fat content of 3.36%, while the treatment using 0.5% lime concentration and a 30-minute boiling time had the highest fat content of 3.59% [47].

Crude fiber

According to Tsegay et al. [45], the percentage of crude fiber has an average value of 1.69% and ranges from 1.39 to 2.05%. However, because pericarp tissue is eliminated during cooking and washing, the nixtamalization procedure or alkali cooking reduces the amount of insoluble dietary fiber [52], by rupturing cell walls, heating increases the number of soluble polysaccharides [35].

Total ash

The proximate composition of meals includes ash content, which contains several minerals. According to Tsegay et al. [45], the value of ash content is a combination of inorganic components in the dietary samples. According to Salazar et al. [53], whereas flours processed with 1.5 and 2.0 g/100 g had greater ash contents (20.09 and 21.35 g/kg, respectively), those processed with 0.5 and 1.0 g/100 g calcium hydroxide had ash contents that ranged from 15.98 to 17.82 g/kg. Nixtamalized maize flour contains more calcium as a result of the nixtamalization process [35].

Carbohydrate

The first dominant chemical component of maize is carbohydrates [44]. According to Kadir et al. [47], the carbohydrate content for nixtamalization treatments ranged from 74.44 to 75.36%. For each lime concentration, boiling maize for (30 or 60 min) results in a different percentage of carbohydrates.

Energy

The energy content of the meal is crucial to determining how it will affect human health, especially when it is sold to consumer groups with high health awareness. Protein, fat, and carbohydrates all contribute to the food samples computed caloric value, with fat making up the majority (9 kcal/g), and protein and carbohydrates making up roughly 4 kcal/g [7]. Due to this, composite flour blends with a high proportion of soybean flour have the highest fat levels and demonstrate the highest energy content, whereas those with a low proportion of soybean flour have the lowest energy content [7] (Table 1).

Anti-nutrient composition of maize

Trypsin inhibitors, phytate, tannins, oxalate, hemagglutinins, and saponins are a few of the unfavorable ingredients in maize that may prevent the absorption and utilization of important minerals like calcium, magnesium, iron, and zinc, which can lead to mineral deficiencies [55]. Yellow corn flour and popcorn flour both contain phytate in amounts between 0.85% and 0.64% to bind minerals. It creates complexes with

Table 1: Proximate contents of maize and nixtamalized maize flour [35, 54].

MC%	CP%	CF%	Fib%	Ash C%	CHO%	E. Kcal/100g
9.3 - 10.2	9.7 - 11.5	4.2 - 6.0	0.2 - 3.3	1.4 - 2.9	68.4 - 73.1	361.4 - 385.7
7.6 - 10.2	7.48 - 11.6	3.36 - 3.59	1.39 - 2.05	1.5 - 2.0	74.4 - 75.4	382.87

Note: MC = moisture content, CP = Crude protein, CF = Crude fat, Fib = fiber, CHO = Carbohydrate, E. Kcal = Energy kilo calorie.

Table 2: Anti-nutritional contents of nixtamalized maize [54].

Phytate%	0.61 - 9.86
Tannin%	0.6 - 1.3
Oxalate%	1.0 - 4.71

multivalent cations including Ca, Mg, Fe, and Zn that make them inaccessible to living things [55]. Oladapo et al. [56] showed that high phytate concentration in cereals decreases the absorption of calcium in cereal grains. Protein digestibility is decreased by the tannins' compound formation with proteins [56] (Table 2).

Functional properties of nixtamalized maize flour

The term "functional properties" refers to a specific ingredient that is present in the right amount and processed under the right conditions so that it contributes to the goods' desired sensory qualities, frequently via interacting with other food ingredients. Functional qualities describe a material's capacity to contain water and oil or fat, emulsify them, and produce products with a firm consistency when heated and cooled. These include viscosity, emulsion, gel and foam production, film production, water and fat absorption, and viscosity [57]. For usage as ingredients in food product applications, it is required to assess the functional qualities of the flours (bulk density, water absorption capacity, oil absorption capacity, etc.). According to Bedolla and Rooney [58], the nixtamal's ability to absorb water throughout the cooking and resting stages is a crucial element in determining the product's humidity, which affects the grain's viscoelastic qualities when it is converted into mass (Table 3).

Cereal-to-legume blending

Reasons for blending

The majority of the world's population obtains its calories, protein, B vitamins, and minerals from cereal-based meals, which are the most essential dietary sources [59]. However, cereal grains are low in protein due to the poor-quality biological value or lower essential amino acids, considered a limiting factor in cereals [60]. Legumes, including pulses, according to Amjad et al. [61], they have long been regarded as a dietary staple due to their about three times higher protein content than cereals. In Ethiopia, the economic security of food and nutrition depends heavily on pulses. Due to rising demand on both domestic and international markets, pulse production and supply have recently increased, boosting smallholders' income [62]. According to Oghbaei and Prakash [63], cereals and legumes (pulses) are important dietary components that significantly increase a person's nutrient intake. They are a significant source of calories, protein, dietary fiber, phytochemicals, vitamins, and minerals. Cereals can be supplemented with other grains or pulses in a different ratio to make up for the lack of nutrients in the cereal [17]. According to Nawaz et al. [64], the development of high-quality food product materials can be influenced by the incorporation of different flours into blends in the right proportion. To increase their nutritional worth, cereals are frequently fortified with lysine or proteins from pulses. Food made from legumes has a higher protein content as a result of pulses being a source of protein and other nutrients [65]. However, most pulses do not offer suitable viscosity and cause a problem with the binding, holding texture, and shape of the food snack in low moisture shelf-stables [60].

Table 3: Functional properties of nixtamalized maize.

Bulk density	WAC	WAI	OAC
0.63	159	2.27	88.82
0.61	163	2.28	88.9

Note: WAC = Water absorption capacity, WAI = Water absorption index, OAC = Oil absorption capacity.

A blending of QPM and soybean

A new variety of maize called quality protein maize has the same amount of protein as regular maize variants. However, compared to normal maize, QPM's protein quality is higher and contains the two important amino acids lysine and tryptophan. QPM was created by the breeders at the International Maize and Wheat Improvement Center in Mexico to lessen the lack of two important amino acids and their impact on the global population [66]. In order to develop diversified foods that provide nutritional security for various food groups and satisfy the need for protein among other social groups, the QPM can be used. In the world's population, soybean seed is a substantial source of protein. The average protein content of soybean reaches around 40%, which is higher than the most common beans; most common beans have a protein content of about 20 to 25%. Consequently, soybean-based meals are a valuable and desirable product for human nutrition and livestock feeding because of their all-essential amino acids with less cost than high-quality protein sources [67]. Enyisi et al. [43] claim that maize contains 8 - 12% protein, which is a large amount. However, combining cereals with legumes or pulses that are higher in lysine and tryptophan can work well together and provide protein that is of higher quality. Micronutrient levels in QPM are lower, and many of them can be lost during the production of different food products [68]. The nutritional content of foods based on cereal has grown because of the addition of legumes like soybeans to cereals like QPM. According to Buta and Emire [69], soybeans have a high protein content that serves as a natural protein supplement to traditional diets. Because of the lysine, tryptophan, and methionine that the high-protein maize contributes, the protein quality of cereal-legume blends improves [70]. Food items used in the treatment or prevention of malnutrition include soy-based products [70]. As a result, the treatment of nutritional issues will be considerably impacted by the QPM and soybean blend.

Tortillas

The product

In Mexico, tortillas are one of the most common dishes eaten. To create food products made from maize, such as tortillas, corn chips, tortilla chips, and taco shells, maize grains are being nixtamalized [71]. Tortillas are food made domestically from nixtamalized maize. About 11 million tons of maize are consumed as food in Mexico each year, which equates to about 79.5 kg of tortillas consumed per person in rural regions and 56.7 kg in urban areas [72]. However, tortillas play a crucial role in Central Americans' nutrition and cuisine, and today, certain nations are becoming aware of the health advantages of tortillas, which are a source of nutrients for tortilla consumers [73].

The making of tortillas

The tortilla is the primary food item made from nixtamalized corn. The tortillas are made with either fresh masa or dry masa flour that has calcium added. Dry masa flour tortillas are used to create more than 2.7 million tons of products industrially each year in Mexico [16]. Tortillas are either made at home or in tortilla factories through the nixtamalization process. The flour mixes with water until the well-mixed dough forms, and adequate uniformity for making tortillas [31].

Physical properties and pH of tortillas

Puffing

Tortilla puffing is a subjective test that evaluates the puffing of the tortillas using a score of 1 to 3, where 1 represents little or no puffing, 2 represents medium puffing, and 3 indicates the completeness of puffing [37]. The puffing of the tortillas is caused by the steam generated during baking that causes the thin inner layer of tortillas to exfoliate and cause swelling [73]. According to Méndez-Albores et al. [74], a tortilla will have good puffing when it has two layers that are impermeable to holding the steam that causes the puffing during heating. This property is very important in tortillas as it indicates whether the masa from which the tortillas are made had an adequate degree of cooking or inadequate heat exposure on both sides of the tortillas during the baking process [75]. This phenomenon is known to occur when the maize dough has the proper water content as a result of a good nixtamalization process.

Rollability

Rollability is the process of rolling tortillas over a tube with a diameter of 1 - 2 cm. The extent of the breaking is then measured using a scale of 1 to 3, where 1 denotes tortillas with no breakage, 2 denotes partial breaking at the center and edges of the tortillas, and 3 denotes tortillas that have been completely flattened [37]. According to Méndez-Albores et al. [74], tortillas with good rollability have a value near 1, which is defined as no breaking; as a result, the tortillas that are on the edge of acceptable quality margins are described as having a soft texture and rolling without breaking. Since tortillas are commonly consumed as wrapping for other foods, this property is interpreted as elasticity, or sufficient capacity to roll and fold (without breaking). For tortillas, a fracture strength value of 0% is desirable [76].

Firmness

The texture of foods is an important parameter representing the term firmness, softness, or hardness; the degree of hardness and texture can be described as chewiness and characterizes chewiness, tenderness, and toughness [77]. Rapid firmness or staling of corn tortillas is a characteristic of corn tortillas. The fresh tortillas are soft and flexible, but after some hours, later tortillas will be firm and fragile with easy to break when rolled or folded [78]. The Firmness and cohesiveness of tortillas fortified with pinto beans were negatively affected by the addition of bean flour [78]. However, this effect partially comes with the addition of hydrocolloids. According to Treviño-Mejía et al. [79], the textures of tortillas made solely from nixtamalized maize flour and tortillas prepared from maize flour combined with bean flour were 2.01 N and 2.37 N, respectively. The addition of common bean flour to nixtamalized maize flour affects the tortillas' ability to withstand the puncture test or make them more breakable with reduced firmness [79].

pH

As it influences the flavor and shelf life of items, the pH of food products is a crucial parameter [27]. The pH of the cooking liquor rises from 7 to 12 due to the addition of calcium hydroxide during the nixtamalization process. The calcium content of the food increases due to the necessary component of the diet and the increases in pH that enable partial pericarp removal [80]. According to Méndez-Albores et al. [81], the pH value of corn tortillas cooked using the conventional nixtamalization method in Mexico, which involves using 3% (w/w) lime, was 8.33. While Martínez-Albores et al. [81] made tortillas from extruded fresh masa with pH values of 6.98. Tortillas made with 0.25 and 0.50% (w/w) lime concentrations presented average pH values of 6.96 and 7.97, respectively [75]. The tortillas with a pH between 7.1 to 7.2 retain the characteristic flavor with a good shelf life [58] (Table 4).

The mineral composition of tortillas

Minerals are essential nutrients that are needed to facilitate the proper functioning of specific organs in the body. The increase in the calcium content of tortillas is one of the most significant effects of nixtamalization [82]. Calcium is an essential mineral because it increases during the nixtamalization process and plays a crucial role in bone formation [83]. Nixtamalized maize flour is rich in minerals like potassium, the most abundant mineral in maize flour, and magnesium in higher amounts [7]. Bressani [29] reported tortillas from 5 different families had an increase in calcium content from 48.3 mg/100 g in maize to 216.6 mg/100 g in a tortilla. Calcium and phosphorus balance improved, whereas Fe was 4.8 mg/100 g in maize to 7.0 mg/100 g in the tortillas and the Zn content of 4.6 mg/100 g in maize to 5.4 mg/100 g in tortilla concentrations (Table 5).

Conclusion

Due to the great reliance on maize as a staple food in Africa and its poor nutritional value, research is needed to increase the nutritional content of diets based on maize. One of the ancient methods for treating maize to improve its nutritional value and create food kinds based on the grain is nixtamalization. Moreover, food products made from nixtamalized maize flour enriched with soybean might alleviate the protein and energy malnutrition problem prevalent in most developing countries, including Ethiopia. The nutritional value of maize protein is improved by the nixtamalization process. The poorest quality protein component of maize, zein, and the digestibility of the majority of the essential amino acids are likely to be the causes of the qualitative changes. Besides, the quality of soybean protein can be comparable to that of animal sources such as milk and meat. It's a suitable and inexpensive substitute for animal proteins, it is used in combination with maize in a community where maize is a staple food. Finally, proper optimization of the nixtamalization process with proper formulation of maize with soybean flour enables the production of relatively better nutrient-rich maize-based food.

Table 4: Physicochemical properties of nixtamalized maize and pH of tortillas flour.

Puffing (Scale 1 - 3)	2.67	2.33
Rollability (Scale 1 - 3)	1.00	1.00
Firmness (N)	4.76	5.06
pH	8.7	8.64

Table 5: Mineral content of nixtamalized maize.

Calcium (mg/100 g)	Iron (mg/100 g)	Zinc (mg/100 g)	Ref.
669.15	3.62	2.14 ± 0.05	[83]
169.83	3.66	2.14	[84]
126.93	4.52	-	[7]

Acknowledgements

None.

Conflict of Interest

None.

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