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Comparative Analysis of Nutritional Value, Mineral Composition, and Phytochemical Profiles in Imported and Locally Grown Grains.

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ABSTRACT

Crops cultivated locally are considered among the most important crops worldwide because of their abundant essential nutrients and significant economic potential. This study evaluates the nutritional value, mineral composition, and phytochemical compounds of locally cultivated grains compared to imported varieties in the Sulaimani governorate of Iraq. Locally grown wheat, lentils, chickpeas, and maize were sourced from the Directorate of Agricultural Research, which promotes high-quality products from regional farmers, while imported grains were obtained from a retail outlet known for its diverse offerings and high consumer demand. Analytical results revealed that locally grown chickpeas had the highest fat content (5.23%), while lentils exhibited superior protein levels (25.11%) and the highest dietary fiber composition (29.31%). Additionally, local maize and wheat displayed the highest carbohydrate (73.87%) and moisture (13.07%) contents, respectively. Mineral analysis demonstrated that local grains consistently exhibited high concentrations of essential minerals. Lentils contained notable levels of iron, zinc, manganese, and potassium (7.69, 4.80, 16.36, and 957.33 mg/100g, respectively), while chickpeas were rich in magnesium and calcium (136.13 and 158.80 mg/100g, respectively). Enhanced energy composition observed in these local crops is likely attributed to a combination of genetic factors and favorable environmental conditions. Furthermore, the assessment of phytochemical constituents, namely phenolic compounds, flavonoids, and tannins, indicated a more robust antioxidant profile in locally produced maizeze grain (174.25, 5.77 and 46.70 mg/100g) relative to imported counterparts, respectively. The findings underscore the potential benefits of local crop cultivation to enhance food security and promote sustainable agricultural practices while delivering economic and health advantages to the community. The correlation analysis indicated that there is a strong positive correlation between protein and dietary fiber, while strong negative correlations exist between protein and carbohydrate (g), and phenolic acids and ash, with weaker correlations seen in other cases, such as Mg and Mn.

Keywords: Phenolic compounds, flavonoids, tannins, nutritional value, mineral content, plant compounds.

INTRODUCTION

Human health and well-being are intrinsically linked to plant-based resources. Of the approximately 50,000 edible plant species, key grain crops, including wheat, chickpeas, maize, and lentils, contribute to over 60% of global dietary energy intake [1]. In developing countries, particularly in sub-Saharan Africa and southwestern Asia, 75% of the population resides in rural areas [2, 3]. Despite advances from the Green Revolution that intensified agricultural production, many people still suffer from food insecurity, largely due to hidden hunger related to protein deficiencies [4, 5]. Exploring crop proteins as an affordable and environmentally friendly source of protein could help address malnutrition issues [6]. Crops are those that are grown primarily for food and are included in the field of agronomy. Staple crops, such as wheat, rice, corn, and beans, are well-known. The primary crops grown can be categorized according to their intended use. Major agricultural categories encompass cereals, oilseed crops, pulses, fiber crops, sugar crops, pasture crops, medicinal crops, root and tuber crops, and vegetable or garden crops, among others. These crops are integral to human survival due to their diverse applications and essential contributions to daily life [7]. Crops such as sugarcane, wheat, maize, rice, barley, and others are major food producers for humans. Globally, various environmental factors affect agricultural yields. Abiotic stressors, such as temperature, heavy metals, drought, water, and salt stress, exacerbate the issue by making Crops hazardous [8]. Agrotechnical factors play an important role in the productivity of crops, and fertilization is one of the agrotechnical factors that affect the mineral and quality of crops. Having an adequate supply of nutrients is one of the most important geotechnics, and fertilization can help [9]. Crops and seeds, rich in proteins and peptides, are considered nutraceutical extracts from functional foods that offer health and medicinal benefits, particularly for humans [10]. Proteins derived from crops and seeds play a vital role in addressing protein-calorie malnutrition in developing nations. Often described as 'poor man's meat,' they supply nutritionally sufficient protein meals to many who cannot afford fish, meat, or dairy [11]. Utilizing proteins from crops and seeds could pave the way for poverty reduction, enhanced nutrition and health, improved food security, and conservation of natural resources in rural regions with limited access to these resources. Crops and seeds provide energy, carbohydrates, minerals, B vitamins, and proteins. Proteins in these crops and seeds are sources of various bioactive peptides that benefit human health [12]. High-protein varieties include wheat, brown rice, millet, cornmeal, oatmeal, amaranth, buckwheat, quinoa, whole-wheat pasta, and seeds and nuts such as flaxseeds, chia seeds, pumpkin seeds, peanuts, walnuts, almonds, sunflower seeds, cashews, along with dates, kiwis, and cumin. However, some locally cultivated crops and seed proteins, essential for ensuring food and nutrition security, remain significantly underutilized [13]. Although plant-based foods constitute a significant portion of diets in developing countries, they frequently fail to fulfil nutritional requirements adequately. While crops serve as essential food sources, they often supply proteins of inferior quality. They are deficient in bioavailable micronutrients, including iron, zinc, iodine, and vitamin A, which are present in limited quantities and exhibit poor absorption rates [14]. Relying solely on cereal based diets, which lack crucial micronutrients, negatively impacts human health and can lead to malnutrition. Micronutrients such as iron, zinc, and provitamin A are crucial for maintaining the functional and structural integrity of biological systems. Globally, deficiencies in these nutrients affect billions, compromising immune function and impeding growth and development. Efforts to address malnutrition include augmenting zinc levels in wheat (*Triticum aestivum* L.) varieties through exploiting genetic variability in germplasm. However, this can only be achieved when soil conditions provide an adequate zinc reservoir for absorption. Research has shown that specific wheat varieties from India and Pakistan contain higher zinc levels, ranging from 4 to 10 ppm. Employing zinc fertilizers alongside pesticides has proven effective in controlling yellow rust in wheat. In regions characterized by significant zinc deficiency in the soil, adopting biofortification tactics resulted in immediate improvements in zinc levels and wheat grain yield [15]. Currently, pulses are receiving more focus for their potential in creating healthy and functional foods. Several research investigations have extensively analyzed the macro and micro-nutrients as well as bioactive phytochemicals present in pulses, emphasizing their advantageous health impacts [16, 17]. Lentils have garnered considerable attention for their unique nutritional and functional properties. A growing volume of studies currently highlights the health benefits and disease-prevention properties of lentils. Data from the FAO indicate that global lentil production reached approximately 2.83 million metric tons in 2008, with Canada (36.9%) and India (28.7%) being the leading producers, followed by Nepal, China, and Turkey [18]. Lentils are a significant component of various international diets, particularly in Mediterranean and Indian cuisine. Known for their soft seed coats, lentils require less cooking time, which helps preserve more nutrients than pulses with harder seed coats [19]. The relatively brief cooking period required for lentils (23–26 minutes) renders them more convenient for consumption compared to most other pulses, which typically necessitate around 70 minutes of cooking time [20]. India is the sixth-largest maize (*Zea mays*) producer globally, accounting for 2% of the overall global production. Maize production experienced a notable surge of approximately 16% during the 2015-16 production period, reaching an estimated 25.3 million tonnes in 2016-17 [21]. Maize ranks as the third most important cereal crop behind wheat and rice, making up a considerable part of poultry feed (49%), human food (25%), animal fodder (12%), industrial uses (12%), brewing (1%), and seed production (1%) [22]. Only 30–40% of maize is used for human consumption, with the larger share (60–70%) serving as animal feed within domestic markets [23]. Over 200 million people rely on maize as a basic food, providing 15% of their protein intake and 20% of their caloric consumption [22]. In India, maize is processed into various products including breakfast cereals, cornmeal, flour, grits, snacks, starch, and tortillas. In several northern Indian states, maize flour is commonly used as a key ingredient in preparing chapattis or flatbreads [24]. Globally, grain-based foods are gaining popularity due to their nutritional value [25]. The nutrients in grains can help reduce the risk of chronic diseases, including type 2 diabetes, cardiovascular disease, and gastrointestinal cancer [26, 27]. In large quantities, these grain foods contain a variety of phytochemicals that can act as chemopreventives, such as phenols, flavonoids and tannins, all of which can be beneficial for health [28]. Essential ingredients in grain are phenolic compounds. They affect the sensory qualities of food items and their potent antioxidant qualities [29]. Plants generate phenolic compounds as stress metabolites to defend against biotic and abiotic stresses [30]. Regarding structure, phenolic compounds are secondary plant metabolites that contain one or more hydroxyl groups attached to at least one aromatic ring. [30-32]. Numerous intrinsic and extrinsic variables, including plant genetics and cultivar, soil composition and growing conditions, maturity stage, and post-harvest conditions, can significantly affect the amount and quality of polyphenols in plant-based meals [33]. Nearly every component of plants, including fruits, roots, leaves, and the outer bark of stems, contains flavonoids. Plant flavonoids contribute to the colour, flavour, and fragrance of seeds, flowers, and fruit, and shield them from environmental factors such as bacteria and UV radiation [34]. The purpose of flavonoids is to support the plant's physiological survival. Other advantages of flavonoids include their use in traditional medicine and as antifungal agents. Most flavonoids originate from biosynthesis, which produces tannins; around 2% of all carbon plants photosynthesize. As a result, flavonoids are among the most abundant natural phenols [35]. The variability in the phytochemical contents of grain crops returns to the utilization of cultivations methods for grain crop production. Research has examined how fertilization affects secondary metabolic components, nutritional content, and plant yield. The application of nitrogen fertilizer rates had a considerable impact on both total yield and components from seed to maturity phases (flowering stage, fruiting stage, and yield), which correlates with the ontogenetic stage of plant growth. Every stage is associated with certain personalities [36-38]. Tannins are secondary phenolic chemicals found in plants that vary in complexity and molecular weight. They are found throughout nature and rank fourth in plant ingredient abundance, behind cellulose, hemicellulose, and lignine [39]. Antibacterial, anticancer, antiviral, and antimutagenic qualities are only a few of the unique qualities that tannins possess. They also have positive effects on human health [40]. There are two different forms of tannins: hydrolysable tannins (HT) and condensed tannins.

Essential grains, such as wheat, and many other legume seeds used by humans and animals are known to have high tannin concentrations. Additionally, it has been demonstrated that the amount of condensed tannin in plant tissue varies depending on the species, plant part, age of the plant, drought, CO2 concentration, soil quality, and cultivation techniques [41]. Locally underutilized crops and seeds have deep roots in the cultural heritage of their respective countries, adapting to specific agroecological regions and flourishing under conventional farming methods with minimal external assistance [42]. Creating strategies to increase the production of locally grown grain and seed proteins would be a crucial move towards sustainably expanding and enhancing global food supplies. Corn stands out as the most commonly imported cereal grain from foreign nations, with its nutrient content varying due to genetic and environmental factors. Wheat is also extensively utilized in European countries, with its nutrient composition influenced by factors like cultivars and environmental conditions [43]. Currently, in Iraq, particularly in the Kurdistan region, there's an increase in the importation of seeds from global markets, with nearly 50% of Iraq's food needs being imported, including crop seeds. Chickpea (*Cicer arietinum* L.), also known as garbanzo bean or Bengal gram, is a legume that was first cultivated in the Fertile Crescent of the Near East, recognized as one of the seven original Neolithic crops [44]. Today, chickpea farming is practised in more than 50 countries, including the Indian subcontinent, North Africa, the Middle East, southern Europe, the Americas, and Australia. Globally, chickpeas are the third most important pulse crop in production volume, following dry beans and field peas. Between 2006 and 2009, the worldwide cultivation area for chickpeas extended over approximately 11.3 million hectares, yielding 9.6 million metric tons (mmt) with an average yield of 849 kg per hectare. India leads in production, averaging 6.38 million metric tons (MT) during this period, which constitutes 66% of the world's chickpea production. Additional significant producers include Pakistan, Turkey, Australia, Myanmar, Ethiopia, Iran, Mexico, Canada, and the USA [45]. Chickpeas are predominantly eaten globally as a seed-based food, influenced by various ethnic and regional factors [46, 47]. Within the Indian subcontinent, chickpeas are frequently divided into cotyledons to prepare dhal and ground into flour for crafting a variety of snacks [48]. In various parts of Asia and Africa, they are commonly used in stews, soups, and salads, and are also enjoyed roasted, boiled, salted, and fermented [49]. These varied culinary uses provide essential nutrition and potential health benefits to consumers. Despite being one of the "founder crops" known for their nutritional and medicinal properties, chickpeas have not received as much research focus as other founder crops, such as wheat or barley [50]. Consumed since ancient times for their excellent nutritional value, chickpeas are also recognized as a functional food offering health benefits. As mentioned earlier, the cultivation methods, analytical method, grain species, grain crop parts, plant age, drought, CO2 concentration, and soil quality determine the nutritional, mineral and phytochemical content of the grain. A key objective is to improve the productivity of locally grown crops, which benefit from shorter transportation times from farms to markets and provide enhanced nutritional value, thereby supporting public health and farmers' financial well-being. Additionally, locally grown crops present substantial economic opportunities and are crucial in reducing environmental impact. The significance of the current study lies in comparing the nutritional quality, mineral composition, and phytochemical content of locally grown crops with those of globally imported ones, aiming to decrease the daily importation of crops to the region and increase demand for locally grown ones. Despite the limited research comparing the nutrient profiles of locally grown crops with those of imported varieties, there has been no comprehensive analysis of the nutritional differences among crops from different countries. Therefore, this study aims to evaluate the variations in nutritional quality, mineral composition, and phytochemical content between domestically cultivated crops such as wheat, lentils, chickpeas, and maize and those sourced from various nations.

Materials and methods

Grain Seeds Sampling

Seeds sampling involved collecting four different grains, both local and imported, from various locations in the Sulaimani region. These grains comprised of wheat (Suli-2, Sham-4), lentil (Flip- 2005), chickpeas (hazarmerd), and maize (KSC-703) sourced from different areas (Figure 1). The imported grains (IG) were acquired from a retail outlet in Sulaimani, which was chosen for its high consumer demand and the diversity of grain varieties available in the market region. The Quartering method was employed for sampling. Three samples from each type were collected and later analyzed in the laboratory. The local grains (LG) samples were obtained from the Directorate of Agricultural Research, Sulaimani, which promotes high-quality produce from regional farmers. Furthermore, it was verified that the batch selected for analysis was free from insect infestation and foreign materials. During the growing season, the seeds of local grain genotypes were sown at the Directorate of Agricultural Research's research farm in Sulaimani, Iraq. The clay loam (pH 7.0) soil in the upper 60 cm layer has an electrical conductivity (EC) of 0.32 dS m^{-1}. A randomized whole block design that was replicated three times was used for the production of local grains. Each plot had three rows, one meter long and separated by thirty centimetres. Subsequently, the samples were placed into sterile polythene bags and preserved at a temperature of 10°C until the commencement of the analysis process. The preparation of the wheat crops included, after cleaning, a debranning treatment using a multi-layer debranning machine across seven cycles, each lasting 3 minutes. A digital weighing scale ensured the consistent removal of bran during the process. After debranning, the wheat was finely ground using an FW100 high-speed universal hand mill (produced by Taisite Instrument Co., Tianjin, China) and passed through a 100-mesh sieve. The processed wheat, now exhibiting various degrees of debranning, was prepared for subsequent analysis [51].

Figure 1: Pictorial representation of grain crops, A:lentil (Flip- 2005), B:maize (KSC-703), C:wheat (Suli-2, Sham-4) and D: chickpeas (hazarmerd).

Determination Nutritional Value of the Grains

Moisture Content (%) Determination

Each sample (2 grams) was precisely weighed and transferred into a crucible. The crucible was then placed in an oven and dried at 105°C for 6 hours, until it reached a consistent weight. Subsequently, the crucible was cooled in a desiccator and then reweighed to determine the percentage of moisture loss [52].

Fat content (%) Determination

To determine the fat content, two grams of each sample were placed in a porous thimble, which was then positioned in the extraction chamber of a Soxhlet apparatus. The chamber was placed above a receiving flask containing petroleum ether. The apparatus was heated on a mantle for 8 hours to facilitate the extraction of crude lipids. Following the extraction, the thimble was removed, and the solvent was evaporated. The flask containing the extracted lipids was subsequently heated at 100°C for 30 minutes to remove any remaining solvent. After cooling in a desiccator, the flask was weighed, and the weight change was used to calculate the fat content percentage [52].

Total Dietary Fiber (%) Determination

The fiber analysis commenced with an acid-base digestion procedure. This involved utilizing 1.25% H_2SO_4, prepared by diluting 7.2 ml of 94% concentrated acid with distilled water to a specific gravity of 1.835 g/ml per 1000 ml, and 1.25% NaOH, created by dissolving 12.5 g of NaOH in 1000 ml of distilled water. The residue remaining from the crude lipid extraction was transferred to a 600 ml beaker, where 200 ml of boiling 1.25% sulfuric acid was introduced. The mixture underwent boiling for thirty minutes, followed by cooling, filtration through filter paper, and rinsing the residue with hot water until neutral washings were obtained. The rinsed residue was reintroduced into the digestion flask for additional digestion with 200 mL of boiling 1.25% H2SO4 for an additional thirty minutes. Subsequently, the mixture was filtered through a porous crucible to isolate the residue, which was then washed with boiling water and subsequently with 15 mL of 95% ethanol. This residue was dried in an oven at 110°C until it reached a constant weight, followed by cooling in a desiccator, transfer to a pre-weighed porcelain crucible, and subsequent weighing. It was then ashed at 550°C for 30 minutes, cooled once more in a desiccator, and re-weighed. The crude fiber content was determined based on the percentage weight loss upon ignition [53].

Protein Content (%) Determination

The protein content of each sample was determined using the established Kjeldahl method [54].

Ash Content (%) Determination

Crucibles intended for ash content analysis were preheated in an oven, cooled in a desiccator, and weighed. Two grams of each sample were then placed into the crucibles and heated in a muffle furnace at 600°C for 4 hours. After cooling in a desiccator, the crucibles containing the ashed samples were reweighed to determine the ash content [54].

Carbohydrates Content (%) Determination

Total carbohydrates were determined utilizing the difference method. This methodology entails subtracting the cumulative percentages of moisture, protein, fat, and ash from 100% [54].

Mineral Composition of the Grains Determination

The concentrations of minerals, including Iron (Fe), Zinc (Zn), Magnesium (Mg), Manganese (Mn), Calcium (Ca), and Potassium (K), were determined using Atomic Absorption Spectroscopy (AAS) [54].

Phytochemical Compounds Determination

Phenolic Acid Contents

Using Folin- Ciocalteu's reaction on the methanolic extract, the polyphenols are identified using the Singleton, Orthofer [55] technique. A spectrophotometer (Pressure Gauge instrument) measures the optic density at 725 nm compared to a blank.

Flavonoids Contents

Using aluminium trichloride ($AlCl_3$) and sodium acetate as reactants, the technique of Meda, Lamien [56], on the methanolic extracts is used to estimate the amounts of flavonoids. A spectrophotometer (Pressure Gauge instrument) is used to measure the absorbance at 415 nm in relation to a blank.

Tannins Contents

Vanilin was used as a reactant on the methanolic extracts, and the tannin assay was conducted using the procedure outlined by Jahan, Vasam [57]. A spectrophotometer (Pressure Gauge instrument) is used to measure the absorbance at 500 nm in relation to a blank.

Statistical Analysis

The data underwent analysis employing GraphPad Prism version (10.4.1 (532) by GraphPad Software, Boston, MA, USA. The significance of differences between the averages was assessed using a Tukey's post hoc test with a significance level of ($p < 0.05$).

Results and Discussion

Nutritional Value of Local and Imported Grains

The nutritional quality showed highly significant ($p < 0.05$) variations among grain samples (Figure 2) for fat, protein, ash and dietary fiber in the grains. In contrast, no significant differences were observed between grain origins. The locally produced chickpeas exhibited the highest fat content (5.43%), compared with imported chickpeas (5.23%). The locally cultivated lentil had the highest protein content (25.11%), compared to the imported lentil (24.08%). Carbohydrate content (%) demonstrated non-significant and highly significant differences between grain origin and grain type, respectively. Among the other grains locally produced maize also exhibited the highest recorded carbohydrate content (73.87 %) compared with imported maize (72.66%). Moisture content (%) also showed significant differences between grain origin and grain type in this recent study. The wheat grain of local cultivation recorded the highest moisture content (13.07%) compared with an imported variety of wheat, which measured 12.07%. Additionally, ash content (%) displayed significant and highly significant differences between grain origin and grain type, respectively. In chickpea, the local sample registered an ash content of 2.93%, whereas the imported sample measured 2.61%. Lentil followed a similar pattern, with the locally produced sample showing (2.60%) ash content compared to (2.39%) in the imported one, Wheat and maize determination recorded ash content of (1.62, 1.32%) and maize (1.27, 1.10%) in the locally and imported gain, respectively. Moreover, the statistical analysis indicated a highly significant difference in dietary fiber content among grain types, while only significant differences were found between grain origins in terms of dietary fiber. In comparison to the imported crops and other local crops, lentil determined maximum dietary fibre composition (29.31 %), while imported lentil (27.14%). Table 1 demonstrates the mean difference and the results of the Tukey's multiple comparison test at a 5% level of significance for grain nutritional value obtained from all study groups (local and imported). The highest fat content was observed in locally grown chickpeas (5.43%). Chickpeas display a higher fat content compared to other crops and pulses, showing a broad genotypic variability. The fat content of chickpeas examined in this study falls within the range reported in other studies, where the total lipid concentration of various chickpea types ranges from 3.77% to 7.41% [58]. Additionally, current study results are consistent with those reported by Madurapperumage, Tang [59], which indicate that lipid content plays a crucial role in food flavor, particularly contributing to the "nutty" taste observed in chickpeas. Chickpea seeds are recognized for their abundance in vital unsaturated fatty acids, including linoleic acid at 55% mg, oleic acid at 21.5% mg, and linolenic acid at 1.43% mg. Additionally, they contain saturated fatty acids like palmitic acid at 9.5% mg and stearic acid at 1.5% mg, as cited in reference [60]. Our results are consistent with several studies indicating that chickpeas generally contain 3.8–10.2% fat, which is higher than other pulse crops like lentils and red kidney beans [61]. Additionally, fat content varies across market classes, with kabuli and desi chickpeas ranging from 3.4–8.8% and 2.9–7.4%, respectively [62]. However, the fat content of locally grown and imported lentils was 1.08%, falling within the range (0.50-1.49%)reported by Ramdath, Lu [63]. The fat content of locally grown and imported maize in this study (4.57%) mirrors that found by Rouf Shah, Prasad [24], although it is lower than that reported elsewhere [64]. The fat content of imported and locally grown wheat was 1.34% and 1.46%, respectively. This finding is consistent with [65], who reported that wheat fat content ranges from 1% to 2.0%. Fats are the primary energy source in foods and contribute to their flavor, taste, texture, and appearance. The variation in fat composition may stem from varietal discrepancies, preservation methods, and distinct processing techniques [66]. This research aims to boost the utilization of domestically grown crops instead of those imported. Furthermore, this data holds promise for enhancing awareness and support for locally sourced crops, thereby generating income for cereal farmers after distribution. An overarching examination of fat content between locally cultivated and imported crops reveals that locally grown grain exhibits higher fat content than the established values of imported crops, potentially owing to the identified high moisture content and varietal distinctions among the crops. Proteins in a product are composed of amino acid chains, and the abundance of these amino acids determines the protein's quality [66, 67]. The study revealed that locally cultivated lentils exhibited the highest protein content, with imported varieties closely following behind at 25.11% and 24.08%, respectively. This finding aligns with research by [68], which suggests that lentils typically contain protein levels ranging from 21% to 31%. Lentil seeds, widely acknowledged as primary sources of dietary protein globally, offer protein levels approximately twice as high as most cereals and comparable to those found in meat. They offer a promising plant-based alternative to animal and soybean proteins in food processing formulations [69]. Similarly, the highest protein content in chickpeas was recorded in locally cultivated varieties (17.63%), consistent with previous findings indicating chickpea protein levels ranging from 17% to 22% [70]. Nevertheless, differences in protein concentration among chickpea varieties highlight the importance of considering specific varieties and growth conditions when evaluating the nutritional composition of chickpeas for importation purposes. Moreover, the protein content of wheat surpassed that of maize, consistent with previous research indicating wheat crops primarily consist of protein (10% to 15%) [65, 71]. The current study revealed a higher protein content in locally cultivated crops than previous research findings, which reported protein contents of 7.5%, 11.6%, and 9.4% for chickpeas, lentils, and maize, respectively [72]. Additionally, in this study, protein content was consistently higher in all locally grown cereals than imported varieties, with varietal differences potentially contributing to disparities in nutrient content. The findings of the current study reveal that locally grown crops possess higher carbohydrate content compared to imported counterparts. Among these, maize cultivated locally displayed the highest carbohydrate content, reaching 73.87%. The proximate carbohydrate composition of maize analyzed in this experiment aligns with prior research, which indicated maize carbohydrate content ranging from 69.66% to 74.55%, primarily in the form of starch [73]. Maize is renowned for its high carbohydrate content and is a significant source of calories [74]. Hence, the locally examined maize hybrids in this study constitute a valuable calorie source and high-quality crops, as grain quality is frequently determined by carbohydrate content, with environmental factors such as planting location exerting more influence on carbohydrate levels than genotype [75]. Variations in climatic patterns, rainfall, and temperature at planting locations can significantly impact the nutritional composition of various crops, with reports indicating that such factors influence maize kernel starch content [76]. Following maize, locally cultivated wheat ranked second in carbohydrate content, at 70.63%. This result is consistent with the findings of a study done by [77] in which the carbohydrates content of wheat was (70-75%) and primarily as starch. This is because wheat, as a cereal grain, naturally stores energy in the form of starch, which is a complex carbohydrate. Starch is the primary reserve material in wheat seeds, supporting the plant's growth during germination and making up the bulk of the grain's dry weight. Furthermore, the observation that the carbohydrate content of locally cultivated legume crops, specifically chickpeas and lentils, in this study is higher than previously reported values (62.3% for chickpeas and 56.4% for lentils [78]) can be attributed to several factors. These may include differences in the varieties of legumes grown, local environmental conditions such as soil type, climate, and agricultural practices, as well as the methods used for measuring carbohydrate content. Local cultivars may have been selectively bred or naturally adapted to accumulate more carbohydrates, or the growing conditions in the current study may have favored higher carbohydrate synthesis and storage in the seeds. Additionally, variations in laboratory analysis techniques can also lead to differences in reported nutritional content. The highest moisture content among the samples analyzed was found in local wheat. In contrast, the moisture content of chickpea was lower than that recorded in a previous study, which reported a value of 11.31% [79]. Determination of grain moisture content is particularly important, as it directly influences the viability of seeds during storage and trading. Variations in moisture content between locally grown and imported crops may stem from different measurement methods, and precise determination is vital for the seed production and trading sectors [80]. This study also found that the moisture content of all four types of crops analyzed was below 14%, a level that reduces metabolic activity and helps prevent rapid spoilage [67]. Both millet and maize exhibited a moisture content of 10.4%. These variations in moisture levels could be attributed to the storage methods employed, as improper storage, such as keeping cereal crops in tightly packed sacks on the ground or in warm environments may alter their moisture content over time. Previous investigations have reported the moisture content of maize as 12.0% [81, 82], which is notably different from the levels observed in this study. In addition to moisture, the study also evaluated ash content, which reflects the mineral composition of the grains [66]. The locally cultivated chickpea exhibited the highest ash content (2.93%) compared to imported chickpea and other crops, aligning with previous chemical analyses that reported chickpea ash content ranging from 2.50% to 3.15% [83, 84]. Conversely, the ash content of lentils in this study was lower than that reported by Dhull, Kinabo [85]. Differences in percentages may arise from variations in crop varieties and environmental conditions. A significant difference in ash content between locally produced and imported crops indicates potential variability in the millet varieties used. Overall, these findings underscore the importance of accurate moisture and ash content assessment for ensuring grain quality, safe storage, and optimal market value. Dietary fiber constitutes a crucial element in whole crops and is believed to contribute, at least in part, to their health benefits. The dietary fiber composition varies significantly among different crops. In the ongoing study, locally grown lentils showed the highest dietary fiber content compared to other crops. The dietary fiber content of locally cultivated wheat in this study falls within the range reported in previous studies, where the total dietary fiber content of wheat ranges from 9% to approximately 20% [86]. Dietary fiber (DF) comprises carbohydrates that remain undigested by the human body. It adds bulk to the intestinal bolus, assists in promoting intestinal transit, aids in preventing colon cancer, and regulates blood glucose levels, among other benefits [87]. DF is categorized into soluble and insoluble forms. Soluble fiber encompasses gums, hemicelluloses, mucilages, and pectins, while insoluble fiber primarily consists of cellulose and lignins [88]. Chickpeas (*Cicer arietinum*) are renowned for their significant dietary fiber content. Approximately 40% of the chickpea husk is comprised of fibre, including cellulose, hemicellulose, and pectin, as cited in reference [89]. In this study, the dietary fiber content of chickpeas surpassed that of previous research findings, where a specific variety of chickpeas exhibited higher total dietary fiber and insoluble dietary fiber content compared to others. The variation is due to the thicker hulls and seed coats in desi chickpeas, which constitute 11.5% of the total seed weight, whereas in other varieties, this figure ranges from only 4.3–4.4% [90].

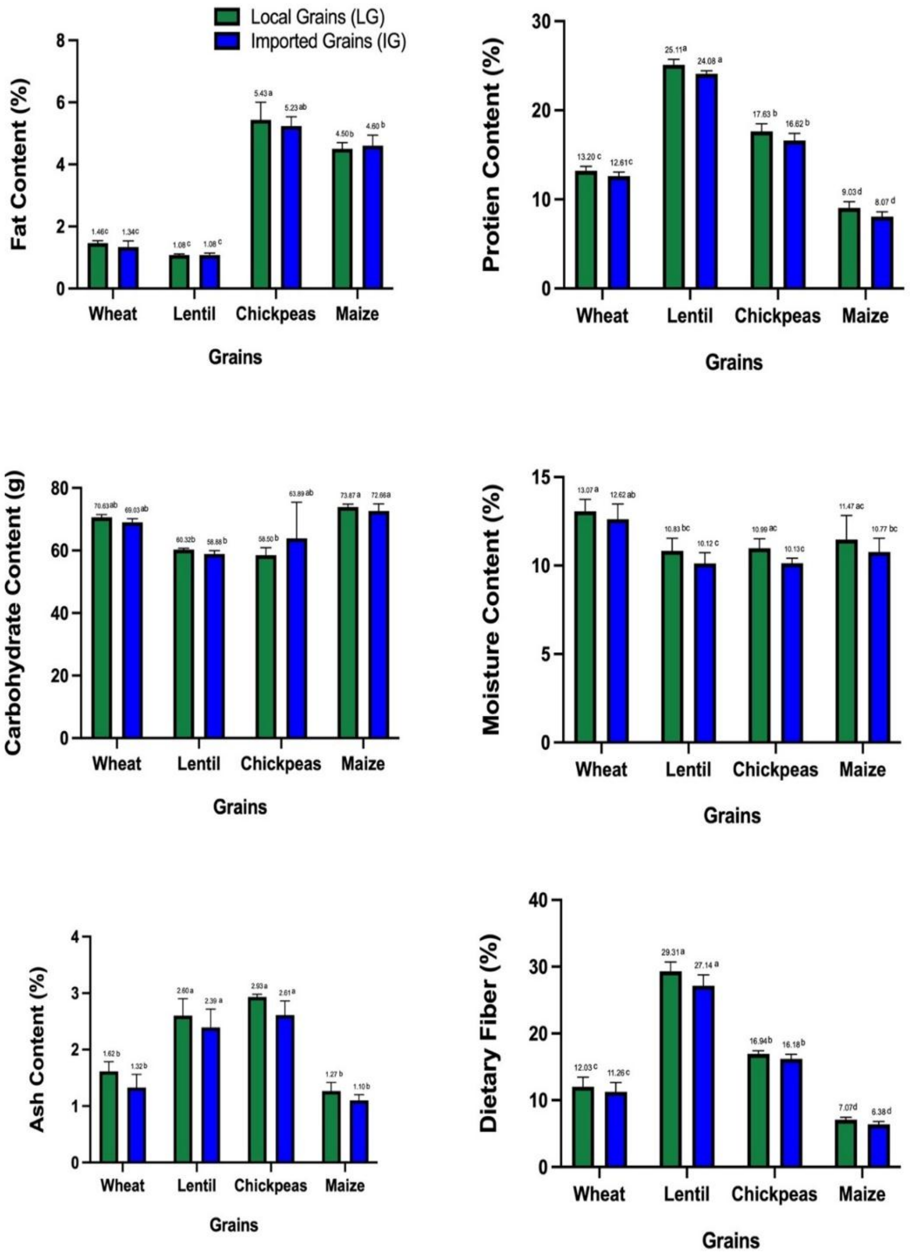

Figure 2: Nutritional value of local and imported grains. Different lowercase letters indicate significant differences according to the Tukey's test ($p < 0.05$). The vertical bars indicate the standard deviation of the mean.

Table 1: Nutritional Value mean difference comparison of local grain (LG) vs imported grain (IG)

Study groups	Fat (%)		Protien (%)		Carbohydrate (%)		Moisture (%)		Ash (%)		Dietary Fiber (%)	
	Mean Diff.	P Value	Mean Diff.	P Value	Mean Diff.	P Value	Mean Diff.	P Value	Mean Diff.	P Value	Mean Diff.	P Value
Wheat:LG vs. Wheat:IG	0.12	>0.9999	0.59	0.93	1.60	1.00	0.45	1.00	0.29	0.72	0.78	0.99
Wheat:LG vs. Lentil:LG	0.38	0.97	-11.91	<0.0001*	10.32	0.13	2.24	0.05	-0.98	0.00	-17.27	<0.0001*
Wheat:LG vs. Lentil:IG	0.38	0.97	-10.88	<0.0001*	11.75	0.06	2.96	0.01	-0.77	0.01	-15.11	<0.0001*
Wheat:LG vs. Chickpeas:LG	-3.97	<0.0001**	-4.43	<0.0001*	12.13	0.05	2.09	0.07	-1.31	<0.0001*	-4.90	0.00
Wheat:LG vs. Chickpeas:IG	-3.77	<0.0001**	-3.42	0.00	6.74	0.56	2.94	0.01	-0.99	0.00	-4.15	0.01
Wheat:LG vs. Maize:LG	-3.04	<0.0001**	4.17	<0.0001*	-3.23	0.98	1.61	0.26	0.35	0.53	4.97	0.00
Wheat:LG vs. Maize:IG	-3.14	<0.0001**	5.13	<0.0001*	-2.03	1.00	2.30	0.04	0.52	0.14	5.66	0.00
Wheat:IG vs. Lentil:LG	0.26	1.00	-12.50	<0.0001*	8.71	0.27	1.79	0.16	-1.28	<0.0001*	-18.05	<0.0001*
Wheat:IG vs. Lentil:IG	0.26	1.00	-11.47	<0.0001*	10.15	0.14	2.50		-1.06	0.00	-15.88	<0.0001*
Wheat:IG vs. Chickpeas:LG	-4.09	<0.0001**	-5.02	<0.0001*	10.53	0.12	1.63	0.24	-1.61	<0.0001*	-5.68	0.00
Wheat:IG vs. Chickpeas:IG	-3.89	<0.0001**	-4.01	<0.0001*	5.14	0.82	2.49	0.02	-1.29	<0.0001*	-4.92	0.00
Wheat:IG vs. Maize:LG	-3.16	<0.0001**	3.58	<0.0001*	-4.84	0.86	1.15	0.63	0.06	>0.9999	4.19	0.00
Wheat:IG vs. Maize:IG	-3.26	<0.0001**	4.54	<0.0001*	-3.63	0.96	1.85	0.14	0.22	0.90	4.88	0.00
Lentil:LG vs. Lentil:IG	0.0033	>0.9999	1.03	0.50	1.43	1.00	0.71	0.94	0.21	0.92	2.17	0.30
Lentil:LG vs. Chickpeas:LG	-4.35	<0.0001**	7.48	<0.0001*	1.82	1.00	-0.16	>0.9999	-0.33	0.60	12.37	<0.0001*
Lentil:LG vs. Chickpeas:IG	-4.15	<0.0001**	8.49	<0.0001*	-3.57	0.97	0.70	0.95	-0.01	>0.9999	13.13	<0.0001*
Lentil:LG vs. Maize:LG	-3.42	<0.0001**	16.07	<0.0001*	-13.55	0.02	-0.64	0.97	1.33	<0.0001*	22.24	<0.0001*
Lentil:LG vs. Maize:IG	-3.52	<0.0001**	17.04	<0.0001*	-12.35	0.05	0.06	>0.9999	1.50	<0.0001*	22.93	<0.0001*
Lentil:IG vs. Chickpeas:LG	-4.35	<0.0001**	6.45	<0.0001*	0.38	>0.9999	-0.87	0.86	-0.54	0.11	10.20	<0.0001*
Lentil:IG vs. Chickpeas:IG	-4.15	<0.0001**	7.46	<0.0001*	-5.01	0.83	-0.02	>0.9999	-0.22	0.90	10.96	<0.0001*
Lentil:IG vs. Maize:LG	-3.42	<0.0001**	15.05	<0.0001*	-14.98	0.01	-1.35	0.45	1.12	0.00	20.07	<0.0001*
Lentil:IG vs. Maize:IG	-3.52	<0.0001**	16.01	<0.0001*	-13.78	0.02	-0.66	0.96	1.29	<0.0001*	20.76	<0.0001*
Chickpeas:LG vs. Chickpeas:IG	0.20	>0.9999	1.01	0.52	-5.39	0.78	0.85	0.87	0.32	0.63	0.76	0.99
Chickpeas:LG vs. Maize:LG	0.93	0.02	8.60	<0.0001*	-15.37	0.01	-0.48	0.99	1.66	<0.0001*	9.87	<0.0001*
Chickpeas:LG vs. Maize:IG	0.83	0.06	9.56	<0.0001*	-14.16	0.02	0.21	>0.9999	1.83	<0.0001*	10.56	<0.0001*
Chickpeas:IG vs. Maize:LG	0.73	0.14	7.58	<0.0001*	-9.98	0.15	-1.33	0.46	1.34	<0.0001*	9.11	<0.0001*
Chickpeas:IG vs. Maize:IG	0.63	0.32	8.55	<0.0001*	-8.77	0.27	-0.64	0.97	1.51	<0.0001*	9.80	<0.0001*
Maize:LG vs. Maize:IG	-0.10	>0.9999	0.97	0.57	1.20	>0.9999	0.69	0.95	0.17	0.98	0.69	0.99

p:tukey's multiple comprision test, *:highly significant

Mineral Composition

Figure 3 illustrates the mineral composition in crops, showcasing levels of iron (Fe), zinc (Zn), magnesium (Mg), manganese (Mn), calcium (Ca), and potassium (K). Statistical analysis demonstrated a notable disparity in Iron (Fe) content across different grain types, with significant discrepancies observed between grain origins. The locally cultivated lentil exhibited the maximum iron (Fe) content (7.69 mg/100g) compared with imported crops (6.77mg/100g). Furthermore, the current study found significant and highly significant variations in Zinc (Zn) content between grain origins and grain types, respectively. The locally cultivated lentil showed the highest Zinc (Zn) content (4.80 mg/100 g) compared with the imported lentil (4.22mg/100g). Locally cultivated chickpea recorded the highest magnesium (Mg) content (136.13mg/100g) in comparison with imported wheat (131.53mg/100g). Lentil grown locally showed the maximum level of manganese (Mn) content, measuring 16.36 mg/100g, compared with imported lentil (16.18mg/100g). Analysis revealed notable variances in Calcium (Ca) and Potassium (K) content across different grain types, with significant distinctions observed based on the origins of the crops. The locally cultivated chickpea exhibited the highest calcium (Ca) content (158.80 mg/100g), while the locally grown lentil showed the highest potassium (K) content (957.33 mg/100g) compared to their imported counterparts. Specifically, imported chickpeas contained 156.17 mg/100g of Ca, and imported lentils contained 54.33 mg/100g and 53.22 mg/100g of Ca. In comparison, other crops such as wheat and maize showed significantly lower levels of Ca, with wheat having 41.00 mg/100g and 37.27 mg/100g, and maize having 10.67 mg/100g and 9.00 mg/100g, both locally and imported, respectively. For potassium (K), locally grown chickpeas had 946.33 mg/100g, while imported chickpeas contained 685.33 mg/100g and 626.67 mg/100g. Locally grown wheat and maize contained 398.67 mg/100g and 384.33 mg/100g, and 284.33 mg/100g and 275.33 mg/100g, respectively, compared to their imported counterparts. Table 2 presents the mean differences and the results of Tukey's multiple comparison test at a 5% significance level for the grain mineral composition across all study groups (local and imported). The current study also indicated that locally grown lentils contained higher concentrations of several essential minerals, including iron (Fe) (7.69 mg/100g), zinc (Zn) (4.80 mg/100g), manganese (Mn) (16.36 mg/100g), and potassium (K) (957.33 mg/100g), compared to imported lentils and other crops. The iron content recorded in this study aligns with the iron content ranges found by [91], which ranged from 7.2 to 8.0 mg/100 g. Similarly, the zinc content in this study corresponds to the results of another study (4.8 mg/100 g) [92]. However, in another study, the iron, zinc, and manganese content of lentils were recorded at lower levels than in the current study, with values of (6.6–7.3), (4.2–4.3), and (1.40–1.62 mg/100 g) respectively [93]. The presence of diverse mineral nutrients such as K, Fe, Zn, Mn, and K holds biochemical significance for seed physiology. Moreover, these nutrients are vital constituents of numerous essential enzymes and function as catalysts and antioxidants. The mineral composition of crops is closely related to the physiological, morphological, and genetic characteristics of the plant species. The comparatively lower mineral concentration in imported crops could be attributed to a dilution effect, as the primary aim of cultivating imported crops is to enhance grain yields compared to locally cultivated crops. Furthermore, earlier research has noted a negative correlation between yield and mineral concentration [94]. The morphological growth of the plant influences the mineral content in crops. Throughout grain development, the minerals within the grain are affected by the quantities transported from the roots and redistributed to the grain by the vegetative tissue through the phloem [95]. The photosynthetic capacity of the vegetative tissue plays a crucial role in determining both the mineral concentration in the grain and its overall yield. Variations in photosynthesis and chlorophyll content are noticeable among different wheat genotypes [96]. A relationship between chlorophyll and Fe concentration has been noted [97], with higher chlorophyll content during final grain filling resulting in increased Fe content in the grain [97]. The enrichment of carbon dioxide has been noted to hinder the conversion of nitrate into organic nitrogen compounds. This limitation on nitrogen availability can reduce photosynthesis in wheat plants, consequently impacting grain quality, including its mineral content [98]. The current study suggests that genetic differences are influential in the mineral concentration of wheat grain. Furthermore, genetic diversity in grain mineral concentration has been observed across various varietal trials [99, 100].

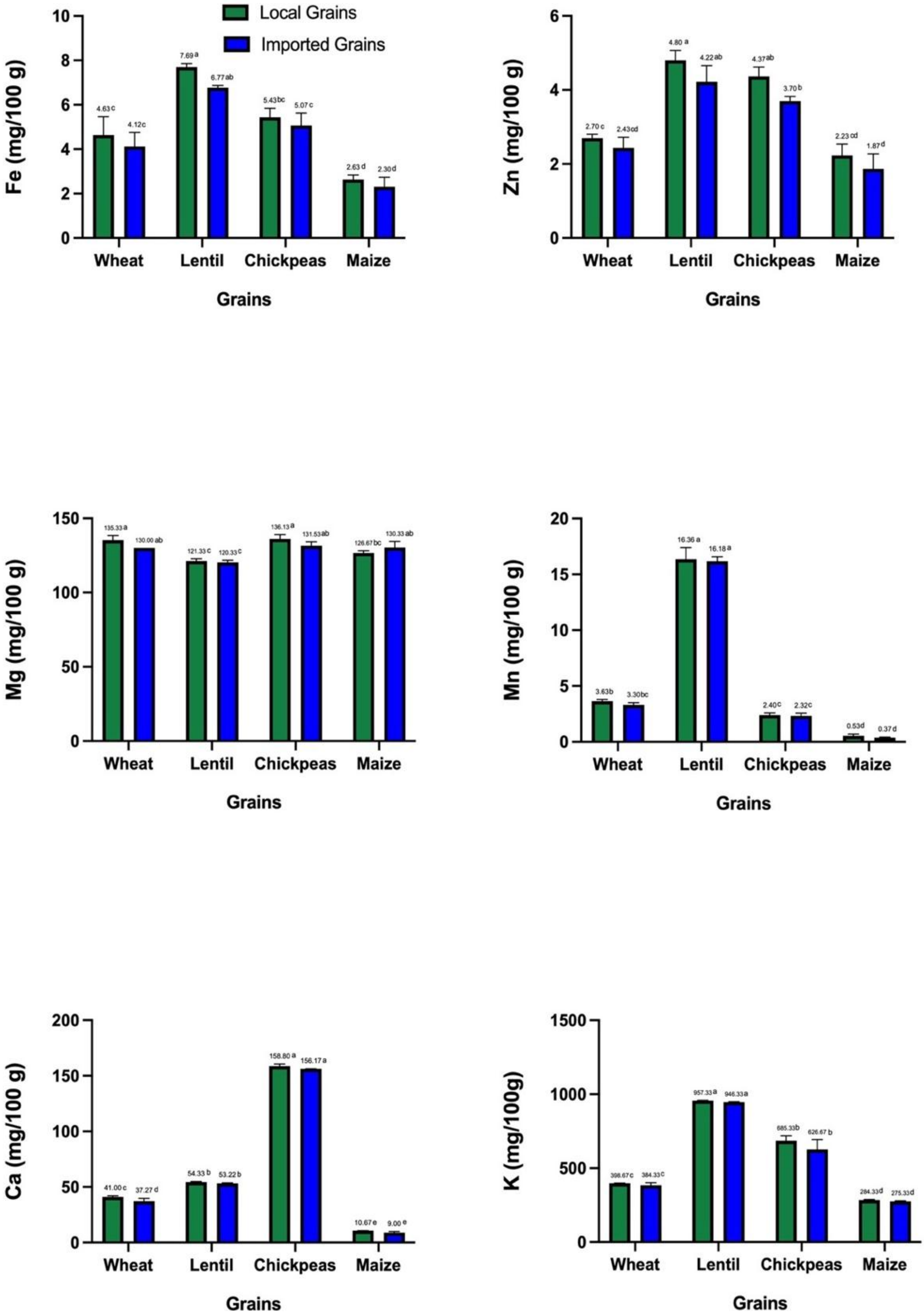

Figure 3: The Mineral Composition of locally cultivated and imported crop, Different lowercase letters indicate significant differences according to the Tukey's test ($p < 0.05$). The vertical bars indicate the standard deviation of the mean.

Table 2: Mineral composition mean difference comparison of local grain (LG) vs imported grain (IG)

Study groups	Fe (mg/100g)		Zn (mg/100g		Mg (mg/100g)		Mn (mg/100g)		Ca (mg/100g)		K (mg/100g)	
	Mean Diff.	P Value	Mean Diff.	P Value	Mean Diff.	P Value	Mean Diff.	P Value	Mean Diff.	P Value	Mean Diff.	P Value
Wheat:LG vs. Wheat:IG	0.51	0.88	0.27	0.94	5.33	0.22	0.33	0.97	3.73	0.03	14.33	1.00
Wheat:LG vs. Lentil:LG	-3.06	<0.0001*	-2.10	<0.0001*	14.00	<0.0001*	-12.73	<0.0001*	-13.33	<0.0001*	-558.70	<0.0001*
Wheat:LG vs. Lentil:IG	-2.14	0.00	-1.52	0.00	15.00	<0.0001*	-12.55	<0.0001*	-12.22	<0.0001*	-547.70	<0.0001*
Wheat:LG vs. Chickpeas:LG	-0.80	0.48	-1.67	<0.0001*	-0.80	1.00	1.24	0.04	-117.80	<0.0001*	-286.70	<0.0001*
Wheat:LG vs. Chickpeas:IG	-0.43	0.95	-1.00	0.01	3.80	0.59	1.31	0.02	-115.20	<0.0001*	-228.00	<0.0001*
Wheat:LG vs. Maize:LG	2.00	0.00	0.47	0.54	8.67	0.01	3.10	<0.0001*	30.33	<0.0001*	114.30	0.00
Wheat:LG vs. Maize:IG	2.33	0.00	0.83	0.05	5.00	0.28	3.27	<0.0001*	32.00	<0.0001*	123.30	0.00
Wheat:IG vs. Lentil:LG	-3.57	<0.0001*	-2.37	<0.0001*	8.67	0.01	-13.06	<0.0001*	-17.07	<0.0001*	-573.00	<0.0001*
Wheat:IG vs. Lentil:IG	-2.65	<0.0001*	-1.79	<0.0001*	9.67	0.00	-12.88	<0.0001*	-15.96	<0.0001*	-562.00	<0.0001*
Wheat:IG vs. Chickpeas:LG	-1.31	0.06	-1.93	<0.0001*	-6.13	0.11	0.90	0.20	-121.50	<0.0001*	-301.00	<0.0001*
Wheat:IG vs. Chickpeas:IG	-0.95	0.30	-1.27	0.00	-1.53	0.99	0.98	0.14	-118.90	<0.0001*	-242.30	<0.0001*
Wheat:IG vs. Maize:LG	1.49	0.03	0.20	0.99	3.33	0.72	2.77	<0.0001*	26.60	<0.0001*	100.00	0.01
Wheat:IG vs. Maize:IG	1.82	0.01	0.57	0.32	-0.33	>0.9999	2.93	<0.0001*	28.27	<0.0001*	109.00	0.00
Lentil:LG vs. Lentil:IG	0.92	0.33	0.58	0.29	1.00	1.00	0.18	1.00	1.11	0.95	11.00	1.00
Lentil:LG vs. Chickpeas:LG	2.26	0.00	0.43	0.62	-14.80	<0.0001*	13.97	<0.0001*	-104.50	<0.0001*	272.00	<0.0001*
Lentil:LG vs. Chickpeas:IG	2.63	0.00	1.10	0.01	-10.20	0.00	14.04	<0.0001*	-101.80	<0.0001*	330.70	<0.0001*
Lentil:LG vs. Maize:LG	5.06	<0.0001*	2.57	<0.0001*	-5.33	0.22	15.83	<0.0001*	43.67	<0.0001*	673.00	<0.0001*
Lentil:LG vs. Maize:IG	5.39	<0.0001*	2.93	<0.0001*	-9.00	0.01	16.00	<0.0001*	45.34	<0.0001*	682.00	<0.0001*
Lentil:IG vs. Chickpeas:LG	1.34	0.05	-0.15	1.00	-15.80	<0.0001*	13.78	<0.0001*	-105.60	<0.0001*	261.00	<0.0001*
Lentil:IG vs. Chickpeas:IG	1.71	0.01	0.52	0.41	-11.20	0.00	13.86	<0.0001*	-102.90	<0.0001*	319.70	<0.0001*
Lentil:IG vs. Maize:LG	4.14	<0.0001*	1.99	<0.0001*	-6.33	0.09	15.65	<0.0001*	42.56	<0.0001*	662.00	<0.0001*
Lentil:IG vs. Maize:IG	4.47	<0.0001*	2.35	<0.0001*	-10.00	0.00	15.81	<0.0001*	44.23	<0.0001*	671.00	<0.0001*
Chickpeas:LG vs. Chickpeas:IG	0.37	0.98	0.67	0.17	4.60	0.37	0.08	>0.9999	2.63	0.22	58.67	0.21
Chickpeas:LG vs. Maize:LG	2.80	<0.0001*	2.13	<0.0001*	9.47	0.01	1.86	0.00	148.10	<0.0001*	401.00	<0.0001*
Chickpeas:LG vs. Maize:IG	3.13	<0.0001*	2.50	<0.0001*	5.80	0.15	2.03	0.00	149.80	<0.0001*	410.00	<0.0001*
Chickpeas:IG vs. Maize:LG	2.43	0.00	1.47	0.00	4.87	0.31	1.79	0.00	145.50	<0.0001*	342.30	<0.0001*
Chickpeas:IG vs. Maize:IG	2.77	<0.0001*	1.83	<0.0001*	1.20	1.00	1.95	0.00	147.20	<0.0001*	351.30	<0.0001*
Maize:LG vs. Maize:IG	0.33	0.99	0.37	0.78	-3.67	0.63	0.17	1.00	1.67	0.71	9.00	1.00

p:tukey's multiple comprision test, *:highly significant

Phytochemical compounds

The phytochemical compounds showed highly significant ($p < 0.05$) variations among grain samples (Figure 4) for phenolic acid (mg/100g), flavonoids (mg/100g) and tannins content (mg/100g), in the grains. The locally cultivated maize exhibited the maximum phenolic acid (174.25mg/100g) compared with imported maiz (166.81 mg/100g). Similar patterns were illustrated in locally cultivated maize in which the highest flavonoids content (5.77mg/100g) was compared with imported maize (4.00mg/100g). As well as in tannins content, the highest content was obtherved in local maize (46.70mg/100g) compared to imported maize (43.73mg/100g). Table 3 illustrates the mean difference and the results of the Tukey's multiple comparison test at a 5% level of significance for grain phytochemicals obtained from all study groups (local and imported). As the main sources of energy, proteins, vitamins, and bioactive substances, grains, including maize, wheat, lentils, and chickpeas, are essential components of a healthy diet worldwide. Important phytochemicals recognized for their antioxidant qualities and possible health advantages are phenolic acids, flavonoids, and tannins. Several studies' results are in line with the result of the current study, in which a study compared the phenolic content in different grain crops. Maiz exhibited the highest phenolic content of (166.4- 605.3mg/100g) [101]. Additionally, de la Parra, Serna Saldivar [102] reported that locally cultivated maiz exhibited the highest phenolic content values (125- 198 mg/100 g) compared to other grain crops. The phenolic, flavonoid, and tannin contents of the same kind of samples vary in the research mentioned above. Varietal variations, weather patterns, when to harvest, and other elements impacting the plants' nutritional value could cause this. Furthermore, a major factor in influencing the quantities of tannins, flavonoids, and phenolic content is the extraction solvent utilized for analysis. [101]. Agronomic techniques, processing techniques, environmental factors, and the genetic composition of the grain all affect its dispersion [103]. Because of customary agricultural methods and adaptation to regional environmental conditions,

locally grown grains frequently display unique phytochemical profiles [104]. On the other hand, even while imported grains are subject to strict quality controls, they may have varying nutritional values because of things like postharvest treatment and various farming methods. [104]. According to numerous researches, local maize can have greater concentrations of flavonoids, tannins, and phenolic acids than its imported counterparts [105]. It is essential to comprehend these distinctions for agricultural practices as well as consumer health. According to a recent study, the phytochemical content of grains varies greatly depending on the growing method and even within the same species. For example, maize is often found to have high concentrations of phenolic acids, including ferulic and p-coumaric acids, as well as specific flavonoid substances like quercetin and kaempferol. Compared to imported samples, local maize varieties typically contain larger quantities of these chemicals [106, 107]. Another major grain, wheat, has a complex antioxidant profile with phenolic acids predominating, and processing techniques can affect how bioavailable these compounds are [108]. Despite having a lower total phenolic acid content than cereals, legumeous grains like lentils and chickpeas have high quantities of flavonoids and tannins that support antioxidant ability [109]. In addition to innate genetic variables, different environmental circumstances and farming practices also contribute to the noticeable disparities between grains that are sourced locally and those that are imported [110]. Comparative studies of wheat have revealed that locally farmed grains typically exhibit more robust phytochemical profiles, likely attributable to traditional farming practices that enhance bioactive compounds accumulation [111]. Though lentils and chickpeas have lower absolute values, local types reveal much greater amounts of these chemicals when assessed. Genetic variety is fundamental to local cultivars, which are usually chosen over generations for qualities improving not only productivity but also sensory and nutritional value. Environmental conditions such as soil composition, climate, and water availability further modify the biosynthesis of phenolic compounds [112]. Agricultural practices, including organic versus conventional farming, significantly impact the accumulation and stability of these bioactive compounds [113]. Processing methods, such as milling, thermal treatment, and fermentation, influence phytochemical stability. While these processes can diminish the overall content of antioxidants, they may enhance the bioavailability of certain compounds [114]. For instance, the breakdown of complex bound phenolics during processing can increase the proportion of free, readily absorbable forms, thereby enhancing nutritional quality [115]. The differences in phytochemical content between local and imported grains are statistically significant and nutritionally relevant. This strong evidence supports the recommendation to prioritize locally sourced grains, attributing greater nutritional value to them.

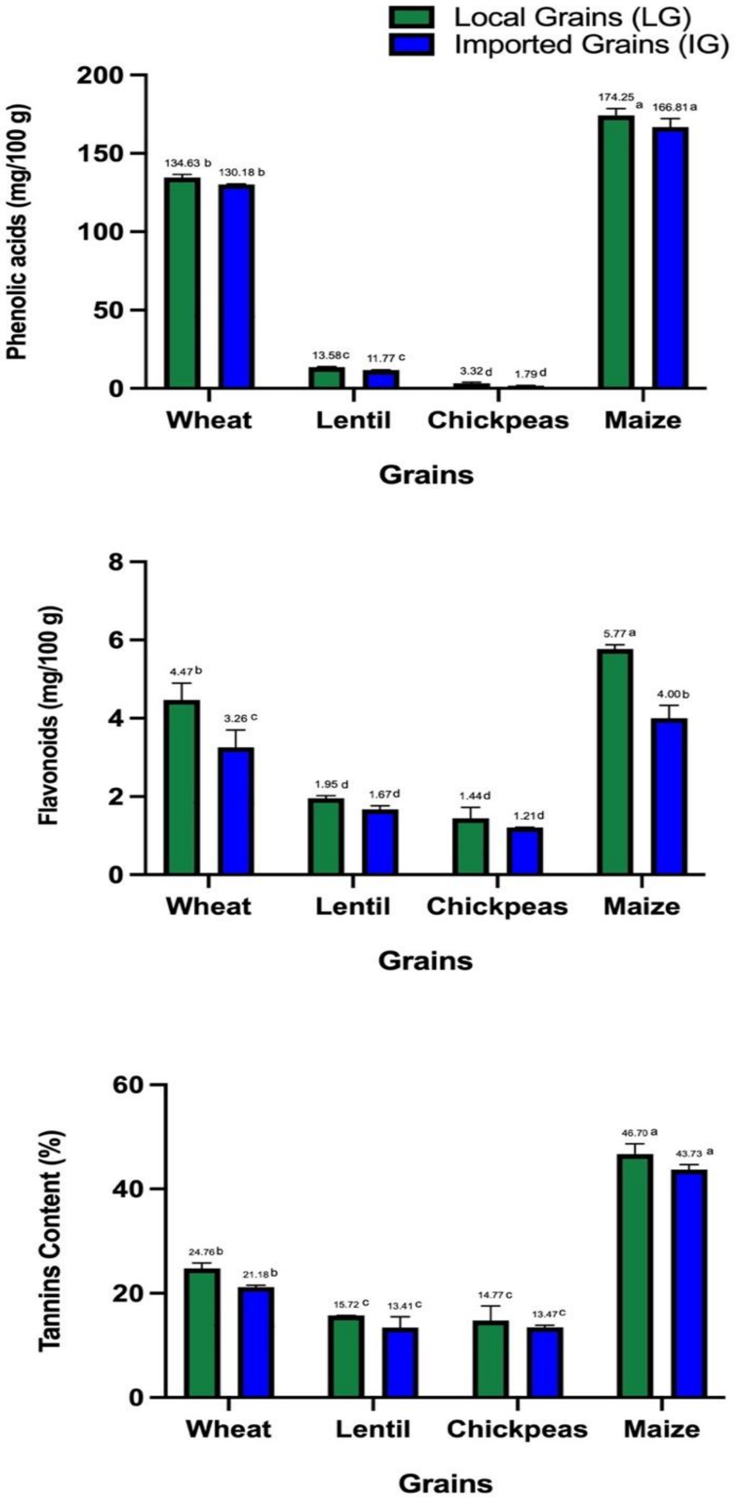

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Figure 4: Phytochemical Compounds of Locally Cultivated and Imported Crop, Different lowercase letters indicate significant differences according to the Tukey's test (*$p < 0.05$*). The vertical bars indicate the standard deviation of the mean

Table 3: Phytochemical compound mean difference comparison of local grain (LG) vs imported grain (IG)

Study groups	Phenolic Acids(mg/100g)		Flavonoids(mg/100g)		Tannins(mg/100g)	
	Mean Diff.	P Value	Mean Diff.	P Value	Mean Diff.	P Value
Wheat:LG vs. Wheat:IG	4.45	0.4482	1.21	0.0012	3.58	0.1409
Wheat:LG vs. Lentil:LG	121.1	<0.0001*	2.513	<0.0001*	9.04	<0.0001*
Wheat:LG vs. Lentil:IG	122.9	<0.0001*	2.8	<0.0001*	11.36	<0.0001*
Wheat:LG vs. Chickpeas:LG	131.3	<0.0001*	3.027	<0.0001*	9.997	<0.0001*
Wheat:LG vs. Chickpeas:IG	132.8	<0.0001*	3.26	<0.0001*	11.29	<0.0001*
Wheat:LG vs. Maize:LG	-39.62	<0.0001*	-1.303	0.0005	-21.94	<0.0001*
Wheat:LG vs. Maize:IG	-32.17	<0.0001*	0.4667	0.4607	-18.97	<0.0001*
Wheat:IG vs. Lentil:LG	116.6	<0.0001*	1.303	0.0005	5.46	0.0082
Wheat:IG vs. Lentil:IG	118.4	<0.0001*	1.59	<0.0001*	7.777	0.0002
Wheat:IG vs. Chickpeas:LG	126.9	<0.0001*	1.817	<0.0001*	6.417	0.0018
Wheat:IG vs. Chickpeas:IG	128.4	<0.0001*	2.05	<0.0001*	7.71	0.0003
Wheat:IG vs. Maize:LG	-44.07	<0.0001*	-2.513	<0.0001*	-25.52	<0.0001*
Wheat:IG vs. Maize:IG	-36.62	<0.0001*	-0.7433	0.0644	-22.55	<0.0001*
Lentil:LG vs. Lentil:IG	1.81	0.986	0.2867	0.8926	2.317	0.5887
Lentil:LG vs. Chickpeas:LG	10.26	0.0033	0.5133	0.3517	0.9567	0.9925
Lentil:LG vs. Chickpeas:IG	11.79	0.0008	0.7467	0.0627	2.25	0.6206
Lentil:LG vs. Maize:LG	-160.7	<0.0001*	-3.817	<0.0001*	-30.98	<0.0001*
Lentil:LG vs. Maize:IG	-153.2	<0.0001*	-2.047	<0.0001*	-28.01	<0.0001*
Lentil:IG vs. Chickpeas:LG	8.453	0.0176	0.2267	0.9654	-1.36	0.9485
Lentil:IG vs. Chickpeas:IG	9.983	0.0043	0.46	0.4775	-0.06667	>0.9999
Lentil:IG vs. Maize:LG	-162.5	<0.0001*	-4.103	<0.0001*	-33.29	<0.0001*
Lentil:IG vs. Maize:IG	-155	<0.0001*	-2.333	<0.0001*	-30.32	<0.0001*
Chickpeas:LG vs. Chickpeas:IG	1.53	0.9947	0.2333	0.9598	1.293	0.96
Chickpeas:LG vs. Maize:LG	-170.9	<0.0001*	-4.33	<0.0001*	-31.93	<0.0001*
Chickpeas:LG vs. Maize:IG	-163.5	<0.0001*	-2.56	<0.0001*	-28.96	<0.0001*
Chickpeas:IG vs. Maize:LG	-172.5	<0.0001*	-4.563	<0.0001*	-33.23	<0.0001*
Chickpeas:IG vs. Maize:IG	-165	<0.0001*	-2.793	<0.0001*	-30.26	<0.0001*
Maize:LG vs. Maize:IG	7.443	0.044	1.77	<0.0001*	2.97	0.3067

Correlation Analysis among nutritional value, minerals composition, and phytochemical compounds

The correlation analysis among the 15 factors revealed several significant relationships across nutritional quality (6), minerals composition (6), and phytochemical compounds (3). There is a strong positive correlation between Protein (%) and Dietary Fiber (%) with (r = 0.982) and between protein (%) and K (mg/100 g) with (r = 0.985). While, there is strong negative correlation (r close to -1) which indicates a strong inverse relationship between protein (%) and carbohydrate (g) with (r = -0.79) and between ash (%) and phenolic acids (mg/100 g) with (r = -0.942) which indicates that as protein content increases, carbohydrate content tends to decrease. There is no correlation (r close to 0) between Mg (mg/100 g) and Mn (mg/100 g) with (r = -0.102). Phenolic acids (mg/100 g) shows strong negative correlations with ash (%) (r = -0.942) and Zn (mg/100 g) (r = -0.921), but strong positive correlations with flavonoids (mg/100 g)(r = 0.929) and tannins (mg/100 g) (r = 0.873). Carbohydrate (g) is positively correlated with phenolic acids (mg/100 g) (r = 0.825) and flavonoids (mg/100 g) (r = 0.761), but negatively correlated with most minerals (Zn, r = -0.796). Mg (mg/100 g) shows very weak correlations with Ca (r = -0.085), and Fat (g) have weak relationships with protein (%) (r = 0.449) and with Mn (r = -0.692). The identified correlations offer significant insights into the nutritional and phytochemical content of the samples. The strong positive relationships among protein, dietary fiber, and potassium indicate that these elements may coexist in specific diets, augmenting their nutritional value. The negative connections between protein and carbohydrate, as well as between phenolic acids and minerals such as zinc, underscore potential trade-offs that should be considered in food formulation or dietary planning. The strong positive relationships among phytochemicals, including phenolic acids, flavonoids, and tannins, highlight the potential of specific foods to act as abundant sources of antioxidants, which are advantageous for health. The negative relationships between phenolic acids and minerals such as zinc indicate that elevated phytochemicals may be associated with reduced mineral content, affecting bioavailability and overall nutritional equilibrium. overall the correlation analysis reveals important relationships among nutritional, mineral, and phytochemical factors, providing a foundation for further research into optimizing food composition for health and nutrition. These findings can guide the development of functional foods and dietary recommendations that balance macronutrients, minerals, and bioactive compounds effectively.

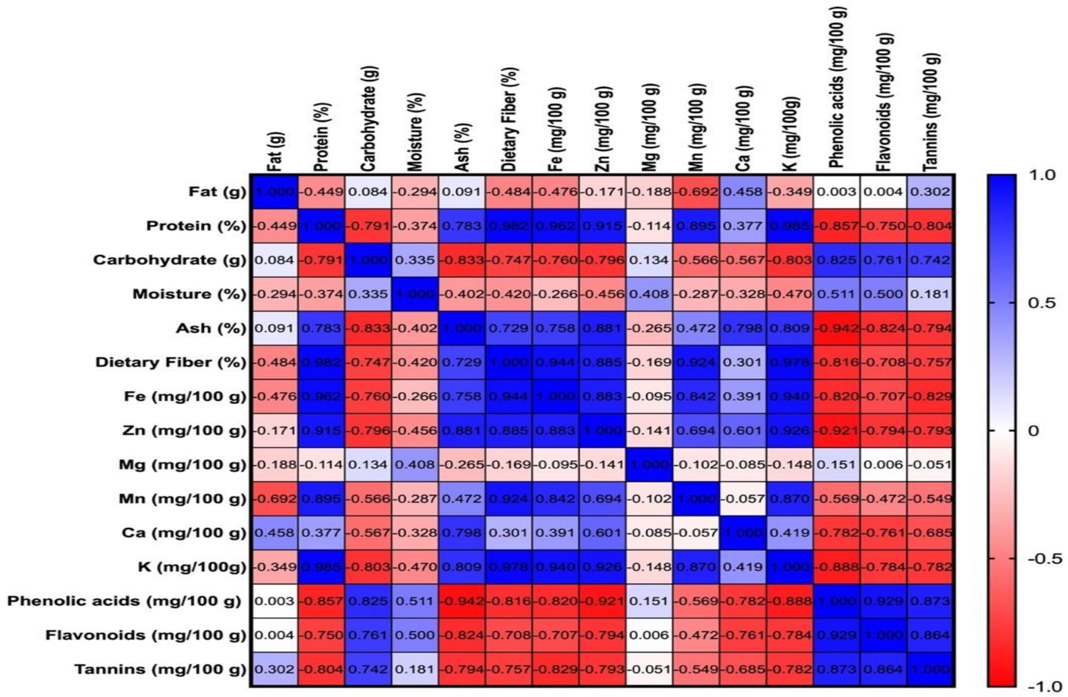

Figure 5**:** Pearson correlation coefficient between all of the parameters investigated. The numbers in each cell represent the Pearson correlation coefficient between the row and column variables. This value ranges from -1 to 1, where 1 indicates a perfect positive correlation: as one variable increases, the other also increases; -1 indicates a perfect negative correlation: as one variable increases, the other decreases; and 0 indicates no linear correlation between the variables. Moreover, the color gradient helps visualize the strength and direction of the correlations; blue shades represent positive correlations and red shades express negative correlations. Moreover, the intensity of the color indicates the strength of the correlation (darker colors for stronger correlations).

Conclusion

Current research shows that locally grown grains, such as chickpeas, lentils, maize, and wheat, have a superior nutritional profile to their imported counterparts. According to the results illustrated from this study, the locally cultivated grains contain significantly higher levels of essential proteins, dietary fibres, and a range of vital minerals such as iron, zinc, manganese, potassium, magnesium, and calcium. The enhanced nutritional value of the grains contributes directly to a higher energy composition, which validates the potential of these grains in addressing malnutrition and improving overall dietary quality. The investigation further emphasizes the critical role of agrotechnical practices, including fertilization, in optimizing the mineral composition and overall quality of the grains. The detailed analysis demonstrates that environmental variables, genetic factors, and specific agricultural treatments significantly affect crop composition. The findings indicate that an optimized cultivation system not only improves yield but also ensures that the grains are rich in phytochemicals, specifically phenolic compounds, flavonoids, and tannins that are responsible for various health-promoting effects. Moreover, the research bridges the gap between nutritional science and sustainable agriculture by highlighting that locally grown grains have the potential to serve as effective alternatives to imported grains. This alternative offers significant socioeconomic benefits for regions prone to food insecurity, where reliance on external food supplies contributes to vulnerability and hidden hunger. The study advocates for a strategic shift towards local cultivation practices that can reduce import dependency, foster rural agricultural development, and leverage nutraceutical properties inherent in these grain crops to confront protein-calorie malnutrition. The findings advocate for augmented investment in local agricultural development, emphasising policies that boost crop quality using advanced agrotechnical approaches and focused research on genetic optimisation. These techniques are expected to enhance the nutritional and phytochemical yield of locally cultivated grains while also promoting sustainable food production systems. With further research to refine these cultivation methods, locally grown grains could fortify community health, reduce poverty, and conserve natural resources, ultimately establishing a resilient framework for future food security.

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تحليل مقارن للقيمة الغذائية وتكوين المعادن والخصائص الكيميائية النباتية في الحبوب المستوردة و المزروعة محليًا.

فحص القيمة الغذائية والتركيب المعدني والمركبات الكيميائية في الحبوب المستوردة مقارنة بالحبوب المزروعة محلياً.

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الخلاصة

تُعدّ المحاصيل المزروعة محليًا من أهم المحاصيل عالميًا نظرًا لوفرة العناصر الغذائية الأساسية وإمكاناتها الاقتصادية الكبيرة. تُقيّم هذه الدراسة القيمة الغذائية والتركيب المعدني والمركبات الكيميائية النباتية للحبوب المزروعة محليًا مقارنةً بالأصناف المستوردة المتوفرة في محافظة السليمانية بالعراق. تم الحصول على القمح والعدس والحمص والذرة المزروعة محليًا من مديرية البحوث الزراعية التي تُروّج للمنتجات عالية الجودة من المزارعين الإقليميين، بينما تم الحصول على الحبوب المستوردة من منفذ بيع بالتجزئة معروف بعروضه المتنوعة وارتفاع طلب المستهلكين عليه. كشفت النتائج أن الحمص المزروع محليًا يحتوي على أعلى نسبة دهون (5.23%)، بينما أظهر العدس مستويات بروتين أعلى (25.11%) وأعلى نسبة ألياف غذائية (29.31%). بالإضافة إلى ذلك، أظهر الذرة والقمح المحليان أعلى محتوى من الكربوهيدرات (73.87%) والرطوبة (13.07%) على التوالي. أظهر تحليل المعادن أن الحبوب المحلية أظهرت باستمرار تركيزات عالية من المعادن الأساسية. احتوى العدس على مستويات ملحوظة من الحديد والزنك والمنغنيز والبوتاسيوم (7.69، 4.80، 16.36، و957.33 ملغ/100 غرام، على التوالي)، بينما كان الحمص غنيًا بالمغنيسيوم والكالسيوم (136.13 و158.80 ملغ/100 غرام، على التوالي). يُعزى ارتفاع محتوى الطاقة الملحوظ في هذه المحاصيل المحلية على الأرجح إلى مزيج من العوامل الوراثية والظروف البيئية المواتية. علاوة على ذلك، أشار تقييم المكونات الكيميائية النباتية، وهي المركبات الفينولية والفلافونويدات و التانين ، إلى ارتفاع محتوى مضادات الأكسدة في حبوب الذرة المنتجة محليًا (174.25، 5.77، و46.70 ملغ/100 غرام) مقارنةً بنظيراتها المستوردة، على التوالي. وتؤكد هذه النتائج على الفوائد المحتملة لزراعة المحاصيل المحلية في تعزيز الأمن الغذائي وتعزيز الممارسات الزراعية المستدامة، مع تحقيق فوائد اقتصادية وصحية للمجتمع. أشار تحليل الارتباط إلى وجود ارتباط إيجابي قوي بين البروتين والألياف الغذائية، بينما توجد ارتباطات سلبية قوية بين البروتين والكربوهيدرات (جم)، والأحماض الفينولية والرماد، مع وجود ارتباطات أضعف في حالات أخرى، مثل المغنيسيوم والمنغنيز

الكلمات المفتاحية :المركبات الفينولية، الفلافونويدات، التانين، القيمة الغذائية، المحتوى المعدني، المركبات النباتية.