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Physical, Total Phenolic and Total Flavonoid Properties of Chia (*Salvia hispanica* L.) Seeds Grown in Kenya

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Abstract

In the recent past, there has been an increased uptake of chia seeds (*Salvia hispanica* L.) by consumers resulting in the increased adoption of chia farming, particularly in Kenya whereby most farmers are practicing subsistence farming and a few farming it commercially. The widespread farming of chia seeds in Kenya translates to increase uptake at household level while offering a niche for industrial processing of chia seeds necessitating the need for studies on physical, total phenolic and flavonoid properties of chia seeds grown in Kenya. The physical, total phenolic and flavonoid properties of chia seeds from two chia planting seasons April to August 2019 and September to December 2019 were evaluated. The physical attributes (length, width and thickness) were determined using a digital vernier caliper while proximate components were determined using AOAC standard methods. The Quencher procedure was used to determine the total phenolic and flavonoid contents. Chia seeds revealed a length of 1.82 to 2.32 (mm), a width of 1.15 to 1.31 (mm) and a thickness of 0.77 to 0.88 (mm). The percentage moisture content of chia seeds was 7.23 to 10.67, the percentage of crude fat was 31.48 to 42.45, the percentage of crude ash was 3.63 to 6.82, and the percentage of crude fibre was 30.95 to 38.65 and the percentage of crude protein was17.82 to 28.97. The total phenolic content observed for chia seeds was 0.73 to 0.87 mg GAE g^{-1} while the total flavonoid content was 0.39 to 0.57 mg GAE g^{-1}. The proximate components of chia seeds varied significantly ($p < 0.05$) based on the chia planting season while the physical properties, total phenolics and total flavonoid contents did not vary significantly.

Keywords

Chia (*Salvia hispanica* L.) Seeds, Properties

1. Introduction

Chia (*Salvia hispanica* L.) cultivation is on the rise in Africa owing to its increasing popularity as a nutritious crop [1]. The chia plant yields chia seeds that have been widely consumed in Argentina, Southwestern United States and Mexico among other countries [2]. Chia seeds can be consumed as whole seeds or their oil extracted and utilized in various food formulations such as in salad dressings, bread, yoghurt, cakes, composite flours, emulsions and cereal bars [3]. In addition to the use of chia seeds in food formulations, chia seeds have found wide applications in the feed industry whereby chia seeds oils and chia seed cake obtained after oil extraction have been used to lower cholesterol levels in meat and egg products while raising the level of polyunsaturated fatty acids [4]. As a result of the increased usage of chia seeds for food and feed, there has been a growing demand for the use of chia seeds as a functional food due to a shift in consumer patterns. Specifically, consumers are opting for foods that offer nutritional value and confer health benefits [5]. Additionally, the utilization of foods with increased potential roles in lowering the risk of chronic degenerative diseases is on the rise. Chia seeds have several reported health benefits in neurological disorders, cancer, cardiovascular disorders and hormonal disorders due to their antioxidant properties [6]. Chia seeds constitute 91 - 93 g/100g of dry matter and of 32 - 39 g/100g oil contents. Specifically, chia seeds have been reported to contain 4 - 6 g/100g ash, 22 - 24 g/100g protein, 18 - 30 g/100g of dietary fibre and 26 - 41 g/100g carbohydrates [7]. Chia seeds are also rich in antioxidants majorly due to flavonoids and phenolic compounds [8]. The physical properties of chia seeds are important in designing and developing chia processing equipment for handling, drying, transportation and industrial use necessitated by the growing interest in the use of chia seeds [9]. As a result, this study aimed at evaluating the physical, total phenolic and flavonoid properties of chia seeds grown in Kenya from different planting regions to provide information that can be adopted by food processing engineers to facilitate equipment design for chia processing in Kenya as well as enable consumers to make informed dietary choices.

2. Materials and Methods

2.1. Sampling and Sample Preparation

Twenty chia seeds samples were obtained from commercial farmers from Mwea, Kivaa, Embu, Nyahururu, Busia, Siaya, Nanyuki, Mweiga, Ol-kalou and Njoro. The chia seeds samples were sorted to remove stones and other debris and then stored at −18˚C to await further analysis. Data collected was for the two main chia planting seasons in Kenya (April-August 2019) and (September-December 2019).

2.2. Determination of Proximate Components, Total Phenolic and Total Flavonoid Content

The moisture content of chia seeds was determined using AOAC method 930.15 [9]. Crude fat was determined by the method described by AOAC method 954.02 [9] while crude fibre was determined by AOAC method 962.09 [9]. Crude protein was determined using Semi-Micro Kjeldahl Method according to the AOAC procedure 978.04 [9]. The extraction and quantification of phenolic compounds was performed as described by [10].

2.3. Determination of Physical Properties

The shape and size of chia seeds were determined by the method described by [2]. For physical properties, three principal dimensions; length (L), width (W) and thickness (T) were measured using a digital Vernier caliper (Pixel Electric: Pixel Electronic Co. Ltd Nakuru, Kenya). The three principal dimensions (L, W, T) were used to calculate the geometric mean diameter (D_g) and surface area (S) of individual grains by assuming that the seeds were ellipsoid. The geometric mean diameter in mm was determined by using the following expression as described by [11]:

$$D_g = (LWT)^{1/3}$$

The surface area of individual chia seed was determined as described by [12] using the formula below:

$$S = \pi D_g^2$$

In addition, the aspect ratio (R) of the chia seeds was calculated as described by [13]. The following formula was used:

$$R = (W/L) \times 100$$

3. Results and Discussion

The physical properties of chia seeds play an important role in developing various equipment for; drying, handling, storage and other processing equipment such as oil extraction. Specifically, this helps in adequate designing of cleaning, grading, separation and moisture determination equipment. Furthermore, these properties aid in the design of machines for gravimetric properties which are related to aeration, storage, drying and transport [9]. From the findings of this study (**Table 1**), the length (mm) of chia seeds obtained from different regions in Kenya ranged from 1.85 ± 0.02 to 2.32 ± 0.51 in the first chia planting season April-Aug 2019. In the second chia planting season (Sep-Dec 2019), the length observed for chia seeds was from 1.82 ± 0.01 mm to 2.04 ± 0.05 mm. These current findings are in agreement with those of [2], who reported the length of chia seeds to be in the range of 1.73 mm - 2.63 mm. The length of chia seeds is affected

Table 1. Physical properties of chia seeds obtained from selected areas of Kenya for the first (April-August 2019) and second (September-December 2019) chia planting seasons.

Area	Length (mm)	Width (mm)	Thickness (mm)	Geometric mean diameter (Dg) (mm)	Surface area (S) (mm^2)	Aspect ratio (R) (%)
Mwea 1	1.90 ± 0.02^{ab}	1.15 ± 0.10^{a}	0.77 ± 0.01^{a}	1.12 ± 0.09^{a}	13.24 ± 0.17^{a}	64.92 ± 0.11^{gh}
Mwea 2	1.87 ± 0.02^{ab}	1.24 ± 0.05^{bcde}	0.87 ± 0.02^{ghij}	1.24 ± 0.03^{cde}	16.27 ± 0.02^{g}	63.62 ± 0.05^{cd}
Kivaa 1	1.92 ± 0.03^{ab}	1.21 ± 0.05^{abc}	0.83 ± 0.01^{bcde}	1.21 ± 0.02^{bcde}	14.92 ± 0.13^{bcd}	62.92 ± 0.05^{b}
Kivaa 2	2.03 ± 0.00^{abc}	1.29 ± 0.05^{f}	0.83 ± 0.01^{cde}	1.26 ± 0.03^{de}	15.71 ± 0.23^{efg}	65.08 ± 0.85^{ghij}
Embu 1	1.86 ± 0.02^{ab}	1.26 ± 0.03^{cdef}	0.87 ± 0.02^{ijk}	1.25 ± 0.^{02cde}	15.68 ± 0.22^{efg}	65.76 ± 0.42^{jk}
Embu 2	1.94 ± 0.01^{ab}	1.22 ± 0.03^{abcd}	0.84 ± 0.02^{cde}	1.22 ± 0.04^{bcde}	15.17 ± 0.42^{cde}	64.05 ± 0.91^{def}
Nyahururu 1	2.02 ± 0.02^{ab}	1.30 ± 0.03^{de}	0.85 ± 0.00^{efgh}	1.27 ± 0.02^{e}	15.72 ± 0.27^{efg}	63.65 ± 0.19^{cd}
Nyahururu 2	2.02 ± 0.01^{ab}	1.27 ± 0.02^{cdef}	0.88 ± 0.01^{jk}	1.27 ± 0.03^{e}	15.53 ± 0.63^{def}	63.75 ± 0.18^{cde}
Busia 1	1.94 ± 0.01^{ab}	1.20 ± 0.03^{abc}	0.80 ± 0.01^{b}	1.20 ± 0.04^{bcd}	15.23 ± 0.04^{cde}	66.47 ± 0.26^{l}
Busia 2	1.82 ± 0.01^{ab}	1.22 ± 0.03^{abcd}	0.84 ± 0.02^{cde}	1.21 ± 0.00^{bcde}	14.31 ± 0.84^{b}	64.96 ± 0.21^{ghi}
Siaya 1	2.02 ± 0.01^{ab}	1.29 ± 0.02d^{e}	0.84 ± 0.02^{def}	1.26 ± 0.01^{de}	15.68 ± 0.15^{efg}	64.61 ± 0.34^{fgh}
Siaya 2	2.04 ± 0.05^{abc}	1.31 ± 0.01^{de}	0.83 ± 0.03^{cde}	1.26 ± 0.02^{e}	14.48 ± 0.24^{b}	65.31 ± 0.06^{hij}
Nanyuki 1	1.93 ± 0.01^{ab}	1.16 ± 0.04^{ab}	0.83 ± 0.01^{bcde}	1.18 ± 0.04^{b}	14.71 ± 0.22^{bc}	62.76 ± 0.45^{ab}
Nanyuki 2	1.92 ± 0.00^{ab}	1.24 ± 0.02^{cdef}	0.87 ± 0.01^{fghi}	1.25 ± 0.00^{cde}	16.17 ± 0.21^{fg}	65.25 ± 0.25^{hij}
Mweiga 1	1.85 ± 0.02^{ab}	1.20 ± 0.01^{abc}	0.82 ± 0.01^{bcde}	1.19 ± 0.01^{bc}	14.61 ± 0.01^{b}	64.88 ± 0.29^{gh}
Mweiga 2	1.94 ± 0.02^{ab}	1.26 ± 0.05^{cde}	0.89 ± 0.01^{jk}	1.26 ± 0.01^{de}	15.54 ± 0.39^{def}	65.67 ± 0.13^{ijk}
Ol-kalou 1	2.32 ± 0.51^{c}	1.25 ± 0.02^{cdef}	0.81 ± 0.01^{bc}	1.24 ± 0.01^{cde}	15.15 ± 0.22^{cde}	62.21 ± 0.45^{a}
Ol-kalou 2	1.94 ± 0.02^{ab}	1.26 ± 0.05^{cdef}	0.84 ± 0.01^{defg}	1.26 ± 0.04^{de}	15.69 ± 0.43^{efg}	64.40 ± 0.38^{efg}
Njoro 1	1.86 ± 0.01^{ab}	1.21 ± 0.02^{abc}	0.82 ± 0.01^{bcd}	1.20 ± 0.03^{bc}	14.83 ± 0.87^{bc}	63.27 ± 0.12^{bc}
Njoro 2	1.93 ± 0.02^{ab}	1.24 ± 0.02^{cde}	0.85 ± 0.00^{efgh}	1.24 ± 0.04^{cde}	15.24 ± 0.75^{cde}	65.77 ± 0.05^{jk}

Values in a column with different letters are significantly different to $p < 0.5$. Data are means ± standard deviation ($n = 3$). 1-First chia planting season (April-August 2019); 2-Second chia planting season (September-December 2019).

by genetic variations. Particularly, studies have revealed that one important determinant of the size of seeds is the rate and duration of endosperm proliferation during the early stages of seed development which is influenced by the genetic makeup of the seed [14]. More so, agronomic practices have been shown to influence the size of seeds. Seeds that have received proper nourishment during germination are usually larger in size [15].

In the first chia season (April-Aug 2019), the width content ranged from 1.15 ± 0.10 mm to 1.30 ± 0.03 mm, while for the second chia planting season, the width content was in the range of 1.22 ± 0.02 to 1.31 ± 0.01. The present findings fall in the range of width content as reported by [2], who informed the width content to be 0.81 mm - 1.32 mm.

The first chia planting season (April-Aug 2019) had chia seeds record a thickness of 0.77 ± 0.01 mm - 0.87 ± 0.02 mm while the second season (Sept-Dec 2019) showed a thickness of 0.83 ± 0.01 - 0.88 ± 0.01 (**Table 1**). Some of the findings of this study on thickness were slightly lower while others were within the range reported by [2], for chia seeds 0.83 mm - 1.40 mm. With regard to the thickness of chia seeds, [16] also reported that the thickness of brown chia seeds was 1.32 mm. The observation of these authors was comparatively higher than our present findings.

The findings of this study revealed the geometric mean diameter (Dg) to be in the range of 1.12 ± 0.09 mm to 1.27 ± 0.02 in the first chia planting season. In the second chia planting season, the geometric mean diameter ranged from 1.22 ± 0.04 mm to 1.27 ± 0.02 mm. The findings of the current study were within the range as the findings of [2], who reported that the geometric mean diameter of chia seeds ranged from 1.10 - 1.54 mm. However, [17] reported a slightly higher geometric mean diameter for chia seeds at 1.28 mm as compared to the present findings of this study. Additionally, [16] reported that the geometric mean diameter of chia seeds was 1.32 mm which was relatively higher than the findings of this study. In the first chia planting season (April-Aug 2019), the surface area of chia seeds was observed to range from 13.24 ± 0.17 mm^2 - 15.72 ± 0.27 mm^2. Focusing on the second chia planting season (Sep-Dec 2019), the surface area of chia seeds obtained from selected areas of Kenya ranged from 14.31 ± 0.84 mm^2 to 16.17 ± 0.21 mm^2. Previous studies have reported that the surface area of chia seeds is 5.42 to 5.79 mm^2 respectively [2]. The values reported by these authors were lower than the findings of this study. What's more, [16] also reported lower values for the surface area of chia seeds at 5.41 mm^2.

The aspect ratio of chia seeds in the first chia planting season ranged from 62.21% ± 0.45% to 66.47% ± 0.26%. The second chia planting season revealed an aspect ratio of chia seeds ranging from 63.62% ± 0.05% to 65.77% ± 0.05%. The area showing the highest aspect ratio was Njoro at 65.77% ± 0.05% while Mwea had the lowest at 63.62% ± 0.05%. Some of the areas sampled such as Ol-kalou showed relatively lower aspect ratios while other areas such as Busia recorded a higher aspect ratio compared to that recorded in literature for chia seeds, whose aspect ratio was reported to be 62.5% ([16] In other studies, [2] reported that the aspect ratio for white and black chia seeds was 62.7% ± 1.5% and 65.3% ± 1.3%. His findings for the aspect ratio of chia seeds are in agreement with the current findings of the aspect ratio for chia seeds obtained from selected areas in Kenya.

The mean percentage moisture content of chia seeds from selected areas of Kenya (**Table 2**) ranged from 7.23 ± 0.13 to 10.76 ± 0.7 and 7.82 ± 0.02 to 9.00 ± 0.11 for the first (April-August 2019) and the second season (Sep-Dec 2019) respectively. The moisture contents revealed in this study for both seasons were relatively higher than those recorded by [18] who reported the moisture content of chia seeds from different regions in Brazil to be 7.14% at Rio Grande do Sul and 5.62% at Mato Gruso. In addition, the current findings were also relatively higher as compared to the moisture content reported in literature of Chilean chia seeds at a percentage moisture content of 5.82% [19]. However, there were significant differences ($p < 0.05$) that were observed with regard to moisture content between areas sampled within the same season and also between areas

Table 2. Proximate composition of chia seeds obtained from selected areas of Kenya for the first (April-August 2019) and second (September-December 2019) chia planting seasons.

Area	Moisture content (%)	Crude fat (%)	Crude fibre (%)	Crude ash (%)	Crude protein (%)
Mwea 1	8.14 ± 0.19^{de}	32.29 ± 0.99^{ab}	34.30 ± 1.00^{ab}	4.23 ± 0.17^{cd}	23.55 ± 0.70^{ef}
Mwea 2	8.87 ± 0.11^{hi}	34.91 ± 0.24^{de}	32.62 ± 0.18^{a}	4.11 ± 0.09^{c}	24.84 ± 0.07^{fg}
Kivaa 1	8.06 ± 0.10^{d}	34.29 ± 0.35^{d}	36.22 ± 0.00^{ab}	4.47 ± 0.76^{ef}	23.96 ± 0.77^{ef}
Kivaa 2	8.24 ± 0.06^{def}	36.85 ± 0.76^{fgh}	36.27 ± 0.47^{ab}	3.92 ± 0.06^{b}	28.17 ± 0.69^{i}
Embu 1	7.66 ± 0.08^{bc}	31.48 ± 0.49^{a}	33.23 ± 0.28^{a}	6.82 ± 0.10^{n}	25.75 ± 0.41^{gh}
Embu 2	9.00 ± 0.11^{i}	33.23 ± 0.59^{bc}	32.86 ± 0.72^{ab}	6.78 ± 0.19^{ab}	28.97 ± 0.40^{i}
Nyahururu 1	8.43 ± 0.14^{fg}	36.01 ± 0.51^{f}	33.07 ± 0.39^{a}	5.13 ± 0.12^{i}	26.44 ± 0.16^{h}
Nyahururu 2	8.34 ± 0.09^{efg}	40.99 ± 0.45^{k}	34.16 ± 0.84^{ab}	5.06 ± 0.02^{hi}	21.52 ± 0.14^{cd}
Busia 1	7.23 ± 0.13^{a}	34.65 ± 0.49^{d}	36.81 ± 0.82^{ab}	6.20 ± 0.00^{l}	23.48 ± 0.49^{gf}
Busia 2	7.82 ± 0.02^{c}	35.84 ± 0.74^{ef}	33.47 ± 0.59^{a}	5.64 ± 0.05^{j}	26.10 ± 0.28^{gh}
Siaya 1	8.48 ± 0.15^{g}	34.11 ± 0.29^{cd}	30.95 ± 0.29^{a}	3.91 ± 0.14^{b}	17.82 ± 0.90^{a}
Siaya 2	8.85 ± 0.04^{hi}	36.47 ± 0.78^{fgh}	31.54 ± 0.24^{a}	3.63 ± 0.14^{a}	22.33 ± 0.39^{de}
Nanyuki 1	10.62 ± 0.02^{j}	37.33 ± 0.29^{ghi}	38.65 ± 0.33^{ab}	4.86 ± 0.88^{g}	22.16 ± 0.12^{cde}
Nanyuki 2	8.79 ± 0.04^{h}	42.45 ± 1.10^{l}	36.33 ± 0.79^{ab}	4.99 ± 0.07^{ghi}	20.63 ± 0.54^{bc}
Mweiga 1	7.48 ± 0.28^{b}	35.80 ± 0.71^{ef}	31.99 ± 0.32^{a}	4.33 ± 0.04^{de}	21.27 ± 0.52^{cd}
Mweiga 2	8.81 ± 0.13^{hi}	39.52 ± 0.18^{j}	33.33 ± 0.10^{ab}	4.89 ± 0.15^{gh}	21.66 ± 0.10^{cd}
Ol-kalou 1	8.90 ± 0.77^{hi}	36.65 ± 0.33^{fgh}	36.27 ± 0.35^{ab}	6.52 ± 0.48^{m}	19.75 ± 0.05^{b}
Ol-kalou 2	8.95 ± 0.80^{hi}	38.22 ± 0.66^{i}	36.37 ± 0.15^{ab}	5.91 ± 0.16^{k}	21.77 ± 0.19^{cd}
Njoro 1	10.76 ± 0.07^{j}	37.50 ± 0.30^{hi}	34.25 ± 0.13^{ab}	4.53 ± 0.02^{f}	23.44 ± 0.49^{ef}
Njoro 2	8.24 ± 0.01^{def}	42.41 ± 1.04^{l}	37.51 ± 0.74^{ab}	4.58 ± 0.09^{f}	20.62 ± 0.11^{bc}

Values in a column with different letters are significantly different to $p < 0.5$. Data are means ± standard deviation (n = 3). 1-First chia planting season (April-August 2019); 2-Second chia planting season (September-December 2019).

sampled in the first (April-Aug 2019) and the second season (Sep-Dec 2019). These significant differences could be attributed to the fact that most of the chia farmers lack the necessary equipment such as moisture meters for checking the moisture content of the chia after drying. The percentage crude fat of chia seeds from the selected areas in Kenya (**Table 2**) from the first and second chia planting seasons ranged from 31.48 ± 0.49 to 37.50 ± 0.30 and 33.23 ± 0.59 to 42.45 ± 1.10 for the first and second season respectively. In other studies, the percentage oil content of chia seeds grown in different regions has been reported to range from 32.2% - 36.8% and 35.6% - 38.6% for samples obtained from various regions in Argentina [20] [21]. The findings of the mean percentage crude fat content of chia seeds observed in both seasons were relatively higher than the value reported for Chilean chia seeds at 30.22 ± 0.08 [19]. In addition, [22] also reported the crude fat content of Mexican chia seeds to be in the range of 21.49%

to 32.68%. More so, [23] reported the lipid content of chia seeds to range from 29.98% to 33.5%. Similarly, most of the areas sampled in both seasons revealed a relatively higher percentage crude fat amount than those reported for Brazilian chia seeds from different regions at 32.16% and 30.17% [18]. Significant differences ($p < 0.05$) were observed in percentage crude fat content in the selected areas in both the first and second season. It is possible that these significant differences could be because variability in chia seed composition is expected between growing locations due to genotype and environmental effects [24]. Further, [25] reported that the effects of temperature, light, soil type and nutrition can affect oil quantity and quality of oil seeds. A study to establish whether oil content can be used to determine the origin of commercially grown chia; [23] established that chia seeds grown in different ecosystems revealed significant differences in the percentage oil content reported. Furthermore, significant differences in traditional oil seeds have been reported to be associated with varying climatic conditions [26] [27]. The mean percentage of crude ash of chia seeds obtained from selected areas in Kenya (**Table 1**) was in the range of 3.91% to 6.82% for the period April to August 2019. In the second chia planting season (Sep-Dec 2019), the mean percentage of crude ash content ranged from 3.63% to 6.78%. From the current findings, most of the areas sampled had a crude ash content that was in the range reported in literature of 5% [28]. However, some regions revealed higher crude ash content compared to that reported in other studies. [22] reported the percentage crude ash of chia seeds from different regions in Mexico in the range of 4.5% to 4.87% while [18], reported that chia seeds from two different regions in Brazil as having a percentage crude ash content of 4.56% and 5.07%. The crude ash levels revealed in this study were however lower as compared to the findings of [29], who reported the crude ash content of chia seeds to be 7.05%. From this study, significant differences ($p < 0.05$) were observed between the first and second chia planting seasons as well as between the different areas sampled. These significant differences could be a result of the different geographic locations, soil type, humidity and climatic conditions in which the chia seeds were grown ([18] Also, literature suggests that as a botanical source, the composition of chia seeds could vary based on the location of growth, due to the genotype and environmental effects and also variability could be expected between years within a location [24]. Additionally, the mean percentage of crude fibre in the first chia planting season (April-Aug 2019) was reported to range from 30.95% to 38.65% (**Table 2**). On the other hand, the percentage of crude fibre contents for the second chia planting season (Sep-Dec 2019) were in the range of 31.54% to 37.51% (**Table 2**). In a nutritional analysis of chia seeds, the current findings of this study for all the sampled areas were relatively lower than those recorded for chia seeds obtained from Jalisco, Mexico which ranged from 39.94% to 41.41%. The findings of crude fibre content of chia seeds obtained from Nanyuki in the first planting season (38.65%) was within the range reported for chia seeds obtained from Sinaloa, Mexico 36.97% to

38.79% [30]. In the case of chia seeds samples obtained from four different regions of Mexico, the crude fibre content was reported to range from 20.10% to 36.15%. This is in agreement with most of the chia seeds obtained from different selected areas in Kenya. Chia seeds from different regions in Brazil also revealed a crude fibre content in the range of 33.37% and 37.18% which compares with most of the areas sampled in this study. Notably, no significant differences ($p < 0.05$) were observed with regard to mean percentage crude fibre content of chia seeds from selected areas of Kenya within the specific areas and between the first and second planting seasons. The mean protein content of chia seeds obtained from selected areas in Kenya in the first chia planting season (April-August 2019) ranged between 17.82 ± 0.90 to 26.44 ± 0.16 (**Table 2**). On the other hand, the second chia planting season showed a mean protein content ranging from 20.62 ± 0.11 to 28.97 ± 0.40 (**Table 2**). According to [31], chia seeds have a protein content of up to 20%. Additionally, [32] reported that chia seeds have a percentage protein content of 16.5%. More so, [2] revealed that chia seeds have a protein content ranging from 15% to 25%. In a study by [1], it was observed that chia seeds have 23% mean protein content. In this study, significant differences ($p < 0.05$) between the mean protein contents were observed between the first and second chia planting seasons as well as between the different areas sampled. The significant differences could be attributed to various factors such as influence due to cultivation conditions and practices with several studies suggesting that the use of organic fertilizers can improve protein quality and content as a result of the differences in availability of nitrogen during plant growth [33] [34]. More so, studies have showed that different genes play a role in influencing protein composition in plants [35].

The total phenolic content (TPC) for the first season ranged from 0.74 to 0.87 mg GAE g^{-1} (**Table 3**). In the second chia season, TPC was in the range of 0.73 to 0.87 mg GAE g^{-1} (**Table 3**). According to [19] and [36], the total phenolic content of chia seeds ranges from 0.66 to 1.63 mg GAE/g. The total phenolic content of the chia seeds sampled from all the regions in the first and second seasons were within the 0.66 to 1.63 mg GAE/g. However, some of the current findings were slightly lower than those in previous reports where total phenolic content of chia seeds from two different regions were 0.88 and 0.92 mg GAE/g [30]. Additionally, the results obtained were also lower as compared to the findings of [37], who reported the total phenolic content of chia seeds as 0.94 mg GAE/g. These variations could be explained by the fact that different extraction methods used in different studies have been reported to influence the total phenolic content of chia seeds measured [38]. Notably, there were significant differences ($p < 0.05$) with regard to total phenolic contents between the first and second chia seasons as well as among the different selected areas within a season. These significant differences could be attributed to certain factors such as cultivation techniques and weather conditions [32]. Additionally, [30] reported that differences in phenolics content is affected by external factors such as weather

Table 3. Total phenolic and flavonoid contents of chia seeds from selected areas of Kenya in the first (April-August 2019) and the second (Sep-Dec 2019) chia planting season.

Area	Total phenolic content (TPC) mg GAE g^{-1}	Total flavonoids Content (TFC) mg GAE g^{-1}
Mwea 1	0.79 ± 0.05^{def}	0.44 ± 0.04^{abcd}
Mwea 2	0.87 ± 0.01^{i}	0.48 ± 0.05^{cdef}
Kivaa 1	0.81 ± 0.03^{efg}	0.48 ± 0.02^{bcde}
Kivaa 2	0.81 ± 0.02^{efg}	0.48 ± 0.03^{cdef}
Embu 1	0.75 ± 0.01^{abc}	0.39 ± 0.03^{a}
Embu 2	0.85 ± 0.01^{hi}	0.57 ± 0.03^{g}
Nyahururu 1	0.79 ± 0.01^{def}	0.45 ± 0.03^{abcde}
Nyahururu 2	0.77 ± 0.01^{bcd}	0.51 ± 0.03^{defg}
Busia 1	0.87 ± 0.02^{i}	0.44 ± 0.02^{abcd}
Busia 2	0.73 ± 0.01^{ab}	0.45 ± 0.02^{abcd}
Siaya 1	0.78 ± 0.01^{cde}	0.43 ± 0.02^{abcd}
Siaya 2	0.79 ± 0.02^{def}	0.40 ± 0.05^{bc}
Nanyuki 1	0.87 ± 0.00^{i}	0.50 ± 0.06^{cdefg}
Nanyuki 2	0.84 ± 0.01^{ghi}	0.46 ± 0.07^{abcde}
Mweiga 1	0.82 ± 0.02^{fgh}	0.51 ± 0.06^{defg}
Mweiga 2	0.79 ± 0.03^{def}	0.50 ± 0.06^{cdefg}
Ol-kalou 1	0.74 ± 0.02^{abc}	0.54 ± 0.04^{efg}
Ol-kalou 2	0.76 ± 0.00^{abcd}	0.42 ± 0.04^{abc}
Njoro 1	0.86 ± 0.02^{hi}	0.53 ± 0.04^{efg}
Njoro 2	0.79 ± 0.03^{def}	0.46 ± 0.06^{abcde}

Values in a column with different letters are significantly different to $p < 0.5$. Data are means ± standard deviation (n = 3).

and post-harvest conditions. The total flavonoid content for the first chia planting season ranged from 0.39 ± 0.03 mg GAE g^{-1} to 0.54 ± 0.04 mg GAE g^{-1}. For the second chia planting season (Sep-Dec 2019), the total flavonoid content ranged from 0.40 ± 0.05 mg GAE g^{-1} to 0.57 ± 0.03 mg GAE g^{-1}. Significant differences ($p < 0.05$) in the total flavonoid content were noted between the two first (April-Aug 2019) season and the second (Sep-Dec 2019). Similarly, there were significant differences ($p < 0.05$) among the regions within the same season.

4. Conclusion

The physical, total phenolics and total flavonoid properties of chia seeds grown in Kenya vary based on region the seeds are grown in as well as based on the chia planting seasons. Concerning physical properties, the most abundant proximate components in chia seeds were crude fat, crude fibre and crude protein with Nyahururu, Njoro and Nanyuki, showing the highest amounts of these nutrients. The moisture content of chia seeds from different areas and planting seasons showed a variation necessitating the development of a standard way of drying chia seeds as well as equipment to determine moisture content at farm level. Chia seeds obtained from both planting seasons revealed a similar range of total phenolic and total flavonoid content, thus suggesting that the antioxidant capacity of the chia seeds from both seasons could be similar. Overall, the second chia planting season revealed a higher concentration of the evaluated nutrients as compared to the first season. More studies ought to be conducted profiling the polyphenols in chia seed to provide better insight into their antioxidant properties. Additionally, further studies comparing different extraction methods of total polyphenols in chia seeds ought to be conducted to identify the most appropriate extraction method.

Author Contributions

All authors contributed to the study conception and design of the study. Material preparation, data collection and data analysis were performed by Pauline W. Ikumi, Monica Mburu, Daniel Njoroge, Nicholas Gikonyo and Benjamin Musyimi Musingi. All authors have read and approved the final manuscript.

Data Availability Statement

Research data are not shared.

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Conflicts of Interest

The authors declare no conflict of interest.

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