



Effects of Drying, Packaging Conditions and Storage Time on Proximate Composition of Chia Seeds (*Salvia hispanica*)

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Abstract

The effects of drying, packaging conditions and storage time on proximate composition of chia seeds were investigated. Chia seeds were dried at 63 °C for 30 min (low-temperature long time-LTLT) and at 75 °C for 30 s (high-temperature short time-HTST) using dry oven, air/vacuum-packed and stored for ten weeks. The effect of heat processing (drying) on chia seeds had significant difference ($p < 0.05$) in ash, fiber and fat contents while there was no significant difference ($p > 0.05$) in moisture and protein contents. Except for fiber content, there was no significant difference ($p > 0.05$) in moisture, ash, fat and protein of chia seeds dried at LTLT and HTST before storage. During storage time, there was significant decrease of proximate composition of chia seeds and the decline was the lowest in raw chia seeds followed by seeds dried at HTST and the highest by seeds dried at LTLT. In both drying conditions, ash, fat and protein contents were significantly greater in vacuum than in air packaging although the impact was vice versa for moisture and fiber contents. On the expense of improved shelf life, palatability and digestibility expected as effect of drying, this study suggests HTST and vacuum packaging for storage of chia seeds.

Keywords: Chia seeds; proximate composition; drying; packaging condition; storage.

Introduction

Chia seeds (*Salvia hispanica*) belong to the mint family, and they are native to Central and South America (Nieman et al. 2009). In East Africa, chia is an exotic and new plant, which is gaining popularity because of its nutritional and therapeutic or nutraceutical properties. In 2013, chia seeds were introduced in Tanzania through the Kagera region, where their increasing potential is becoming an economical product (HUDERES 2013). The crop is cultivated twice in a year, and farmers in

Karagwe, Kagera region (Tanzania) are harvesting an average of 0.8 to 1 tonne in 1 hectare. Commercially the crop is cultivated alone, but subsistence farmers are farming by mixing with other crops like maize, sunflower and banana plants.

Nutritionally, chia seeds have significant amounts of lipids ranging between 25 and 40% (w/w), whereby 60% is omega-3 fatty acids. Proteins ranging from 15 to 25% (w/w), ash from 4 to 5% (w/w), and carbohydrates ranging from 26 to 40% (w/w) (Ixtaina et al. 2008,

Coelho and Salas-Mellado 2014, Carrillo et al. 2018). Chia seeds are reported to be reliable, trustworthy sources of minerals, antioxidants as well as vitamins. Besides, they contain approximately 30% (w/w) dietary fibers (Ixtaina et al. 2011). Nutritional composition of chia seeds varies in quality due to different ecosystems, geographical locations, seasonal and cultivation conditions (Ayerza and Coates 2004, Suri et al. 2016). Consumption of chia seeds provides several health benefits originating from their nutritional contents and consumed in natural, unprocessed form after mixed with drinking water, juice, yoghurt, fruit salads or blends with other foods (Kibui et al. 2018).

The matured chia seeds are categorised as grains that need preservation, including packaging after harvesting, prior consumption by final consumers. If improperly preserved, they can undergo a series of physicochemical reactions such as colour changes and oxidation during storage. These changes might affect the quality and lower the nutritional value and shelf life of chia seeds (Huang and Chou 2009). The post-harvest activities such as handling, drying, packaging, and storage conditions, have to be well controlled so that the quality and safety of the seeds are not affected. Oliveira et al. (2016) reported thermodynamic properties of chia seeds related to drying temperature. Different researchers have used different temperature for drying different types of cereals/grains (Kim et al. 2002) for different purposes. The temperature of 40, 50 and 60 °C for drying chia seeds were used for 9 h to attain moisture content of 2.3% (db) (Oliveira et al. 2016). All these studies aimed at reducing the moisture content with less damage to nutritional composition, physical and chemical composition and extend shelf life of seeds. Among all, drying is the most critical method for preserving chia seeds against microbial growth and moisture migration (Malekian 2000). Moreover, chia seeds can also be made into the flour with or without drying and be stored before usage or incorporation into other food products for the production of more

nutrient-dense foods (Haripriya and Aparna 2018).

Chia seeds in the Tanzanian market are packed in different forms using different conditions that include air or vacuum packaging. In addition, the farmers use different materials like glass jars, plastic jars, and low-density polyethylene plastic bags for packaging (HUDERES 2013). The seeds are packed either raw (soon after harvest) or dried form. Other farmers dry the chia seeds to reduce moisture content (lower values < 6%) in order to reduce microbial contamination and enzymatic activities (Oliveira et al. 2016). To the best of researchers' knowledge, there are no data on the nutritional quality composition of raw or processed chia seeds in Tanzania. Hence, there is a need to determine the nutritional quality of chia seeds produced in Kagera region, Tanzania. Therefore, this study was conducted to evaluate the effects of drying, packaging conditions and storage time on proximate composition of chia seeds.

Materials and Methods

Study location

This study was conducted at the Department of Food Science and Technology, University of Dar es Salaam and used some of the laboratory facilities of International Institute of Tropical Agriculture IITA, Tanzania and the Eastern African Regional Hub Food Laboratory located in Dar es Salaam to conduct a proximate analysis of chia seeds.

Sample collection

Chia seeds (*Salvia hispanica*) were harvested in August 2019 and collected one week before the experiment (August 2019) from Karagwe District in the Kagera region located on western shores of Lake Victoria in Tanzania. Freshly harvested chia seeds that were flat and oval, 2.1–2.4 mm long, 1.2 to 2 mm wide and mixed black/grey and white of about 10 kg were cleaned to remove debris. Cleaned seeds were placed in polyethylene bags and transported at the controlled ambient temperature of 25–30 °C to the University of

Dar es Salaam and immediately placed in dark storage at ambient temperature ranging from 25 to 30 °C before analysis.

Study design

In this study, the complete randomized design (CRD) with two treatments each at two levels (2²) was used. The experiment involved two drying approaches (drying chia seeds at 63 °C for 30 min and 75 °C for 30 s) and two packaging conditions (air and vacuum). Samples were then stored at room temperature for ten weeks. Effects of treatment factors were evaluated by random assessments of proximate composition at an interval of one week during the storage time of 10 weeks. Unprocessed (raw) chia seeds packed in air and vacuum were used as control.

Sample preparation and drying

The chia seed samples were weighed to 100 ± 0.1 g using a laboratory electronic analytical balance (Explorer Pro, Switzerland). In total, 60 samples were prepared, each with 100 g and packaged in low-density polyethylene (LDPE) plastic bags with a wall thickness of 30–60 micron. One-third of the samples were dried in an oven (WTB binder Model 78532, Germany) at 63 °C for 30 min (low-temperature long time–LTLT) and another second portion of the samples at 75 °C for 30 s (high-temperature short time–HTST). Drying trays were filled with chia seeds to the depth of 25 mm and placed in the oven at room temperature of 26 °C. Time taken to reach the treatment temperatures of 63 °C and 75 °C were 11 min and 22 min, respectively. The last portion of the sample of raw chia seeds was used as control.

Milling and packaging

Raw and dried chia seed samples were milled by using a laboratory blender (Waring Commercial, made in USA), then sieved through a 0.2 mm sieve, and packed into two different packaging conditions; air and vacuum. The samples packed in air condition named control (raw chia seeds) were coded

R_A), chia seeds dried at 63 °C for 30 min were coded LT_A, and chia seeds dried at 75 °C for 30 s were coded HT_A. The samples packed in vacuum conditions were coded R_V, LT_V, and HT_V for control, chia seeds dried at LTLT and chia seeds dried at HTST, respectively. Raw chia seeds packed in air and vacuum condition (R_A and R_V) were considered as control samples. These notations are used throughout this study. The samples were stored at room temperature for 10 weeks. The samples were taken randomly from the storage room at the interval of 1 week and then analysed in triplicate.

Proximate composition analysis

Proximate composition parameters analyzed were moisture content done by drying the sample in an oven (Binder Model FD 115, Germany) using method No. 950.46 (AOAC International 2005). The crude fibre content was determined using Foss Fibretec™ 1020 (Sweden) by the method no 991.43 (AOAC International 2005). Ash content was determined by incinerating the sample in Muffle furnace (Nabertherm GmbH, made in Germany) at 550 °C for 4 h using method No. 930.05 (AOAC International 2005). Crude fat content was determined by using Soxtec system (Foss soxtec™ 2043, Sweden) using petroleum ether (Sigma Co., St. Louis, MO, USA) as an extraction agent (60–80 °C) using method no. 930.09 (AOAC International 2005). The crude protein content was done by using digestion unit (Foss tecator™ Digester, Sweden), auto distillation unit (Foss Kjeltic™ 8200, Sweden) and titration in accordance with Kjeldahl method using method No. 930.09 (AOAC International 2005).

Data analysis

Data obtained were analysed by using R software version 3.6.1 of 2019 (R Core Team 2012) for one-way repeated measure ANOVA to determine significant variations between raw chia seeds (control) and dried chia seeds (LTLT and HTST) packed in air and vacuum condition, respectively in proximate

composition during storage time (10 weeks). ANOVA assumptions were validated by Shapiro's test, histograms and quartile-quartile plots were used for checking normality, Bartlett's test was used for checking homogeneity of variance and standardized residual plots for independence. Means were separated by Tukeys Honest Significant Difference (THSD) at $p < 0.05$. Results presented in figures and tables as means \pm standard deviation.

Results and Discussions

Moisture contents

Most of the food grains have a hygroscopic characteristic and thus when exposed to various conditions, they move from the grains to the

surrounding, or *vice versa* until there is characteristic balance (or equilibrium) between the moisture they contain and the water vapour in the conditions (Razak et al. 2018). There were no significant changes ($p > 0.05$) in moisture contents between raw and dried seeds. There was also no significant difference in moisture contents between the chia seeds dried at low temperature long time and that dried at high temperature short time before storage. During storage, moisture contents in chia seeds (raw, HTST and LTLT) decreased significantly during the first 6 weeks of storage, thereafter a significant increase occurred until equilibrium moisture content was established and later demonstrated constant moisture content from weeks 8 to 10 (Figure 1).

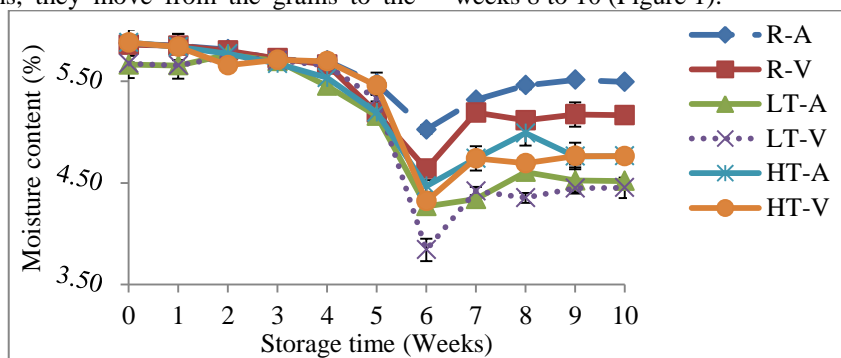


Figure 1: Changes in moisture content of chia seeds packed in air and vacuum conditions and stored at room temperature for ten weeks.

Statistical analysis indicated that the decrease in the moisture content in all the chia seeds during the first three weeks of storage were not significantly different (1st week $p = 0.207$, 2nd week $p = 0.075$, 3rd week $p = 0.067$) (Figure 1). The difference started to appear at the 4th week of storage but the decrease in moisture contents at this week for LT_A and HT_A ($p = 0.148$), HT_A, R_V and LT_V ($p = 0.079$) and that of R_V, LT_V, HT_V and R_A ($p = 0.305$) were not different.

Contrary to the trend observed in the first 6 weeks, moisture contents for all experimented chia seeds depicted a gradual increase at 7th week of storage. During this period, the increased moisture contents for LT_A and LT_V (p

$= 0.126$) and that of LT_V, HT_A and HT_V ($p = 0.064$) were not statistically different; however, that of R_V ($p = 0.000$) and that of R_A ($p = 0.000$) differed significantly from that of other samples. The observed increase in moisture contents resulted into established equilibrium moisture content.

The results revealed that decrease in moisture content was the lowest in raw chia seeds packed in air (R_A) and they retained greater equilibrium moisture content compared to seeds packed in vacuum (R_V) ($p = 0.004$). Chemical reactions existing in the nutrients such as lipid oxidation and hydrolysis of water-soluble vitamins like thiamine, riboflavin, niacin, and folic acid could be additional

factors for the observed moisture rises in the packs (Guiotto et al. 2013, Suri et al. 2016). Chia seeds dried at high temperature short time contained significant higher overall moisture contents than seeds dried at low temperature long time. In both drying conditions, air packaging retained greater equilibrium moisture content than vacuum packaging; however, the existed difference was insignificant [HT_A (5.1388) and HT_V (5.1242); $p = 0.645$] and [LT_V (4.9537) and LT_A (4.9894); $p = 0.261$].

Therefore, in chia seeds, combined effects of vacuum packaging and drying at low temperature long time retains the lowest equilibrium moisture content. Differences in moisture content is plausibly explained by the differences in sizes and shapes of the chia seeds, which range from 2.0 to 2.5 mm length, 1 to 2 mm width, and 0.8 to 1.0 mm thickness (Ixtaina et al. 2008, Suri et al. 2016).

Fibre contents

The profiles of fiber contents characterized in chia seeds samples were examined and presented in Table 1. Drying affected fiber contents because the values in raw chia seeds were significantly higher than in the dried seeds ($p = 0.002$). Heat treatment in food has been reported to break glycosidic linkage in fibers and consequently distorts the architecture of fiber matrix (Margareta and Nyman 2003). The observation in decrease of fiber contents during drying might have resulted from the loss in moisture content and thermal degradation of fiber matrix. The decrease in fiber contents between the chia seeds dried at low temperature long time and those dried at high temperature short time was not significant ($p = 0.072$). By comparing the decrease of fiber contents between the processed and unprocessed chia seeds during storage time, the lowest decrease was observed in raw chia seeds (R) followed by seeds dried at high temperature short time (HTST) and the highest in seeds dried at low temperature long time (LTLT).

Table 1: Fibre content of chia seeds with storage time packed in air and vacuum condition

Weeks	R_A	R_V	LT_A	LT_V	HT_A	HT_V
0	28.88 ± 0.07^b	28.85 ± 0.07^b	28.58 ± 0.03^a	28.38 ± 0.05^a	28.71 ± 0.10^b	28.740 ± 0.14^{ab}
1	28.85 ± 0.08^b	28.84 ± 0.08^b	28.48 ± 0.07^a	28.48 ± 0.08^a	28.70 ± 0.12^b	28.70 ± 0.12^{ab}
2	28.77 ± 0.05^b	28.72 ± 0.00^b	28.43 ± 0.04^a	28.38 ± 0.03^a	28.67 ± 0.04^b	28.55 ± 0.07^c
3	28.69 ± 0.25^b	28.64 ± 0.02^a	28.39 ± 0.02^a	28.29 ± 0.01^c	28.52 ± 0.00^a	28.43 ± 0.00^a
4	28.69 ± 0.25^c	28.64 ± 0.02^d	28.34 ± 0.02^c	28.29 ± 0.00^b	28.52 ± 0.00^a	28.44 ± 0.00^a
5	28.45 ± 0.00^d	28.38 ± 0.03^{bc}	28.18 ± 0.01^a	28.11 ± 0.01^c	28.28 ± 0.05^{bc}	28.23 ± 0.02^a
6	28.37 ± 0.01^c	28.27 ± 0.02^d	28.12 ± 0.01^c	28.05 ± 0.01^b	28.21 ± 0.02^a	28.19 ± 0.01^a
7	28.25 ± 0.00^b	28.18 ± 0.02^b	27.92 ± 0.06^c	27.82 ± 0.05^d	28.11 ± 0.01^a	28.07 ± 0.00^a
8	28.11 ± 0.02^b	27.96 ± 0.03^c	27.63 ± 0.04^a	27.57 ± 0.02^a	27.83 ± 0.05^d	27.70 ± 0.02^c
9	27.64 ± 0.04^b	27.53 ± 0.05^a	27.37 ± 0.02^a	27.28 ± 0.02^a	27.44 ± 0.01^a	27.44 ± 0.00^a
10	27.65 ± 0.04^d	27.54 ± 0.05^a	27.37 ± 0.02^c	27.28 ± 0.02^b	27.44 ± 0.01^a	27.44 ± 0.00^a

Key: Results expressed as means \pm standard deviation ($n = 3$). Samples sharing the same superscript letters in a row for each week are not significantly different at 5% significant level according to Tukey's HSD multiple ranks test.

The differences in fiber contents of chia seeds are ascribed to variations in strength of glycosidic linkage present in fibers molecules due to effects of drying. In all conditions, air packaging had lower amounts of fibers compared to vacuum packaging. This defined how air present in the packs influenced bond breaking and its correspondent fiber reduction.

Statistical analysis indicated presence of strong interactions ($p = 0.000$) between drying and packaging conditions over the storage time. Existed interactions imparted deviation in stability of fibers within storage conditions at a given time. At the 2nd week of storage, there was no significant difference ($p < 0.05$) in fiber contents of HT_V compared to other conditions,

while there was no significant difference observed in R_A , R_V and HT_A ($p = 0.081$) and LT_A and LT_V ($p = 0.331$). On the 10th week when the equilibrium moisture content was attained in samples, the fiber contents in R_A and R_V were significantly different from others, while that of LT_A and LT_V ($p = 0.038$) and that of HT_A and HT_V ($p = 0.062$) were not statistically different. Decreasing of fiber contents at varying patterns has previously been reported in chia seeds dried and stored at different conditions (Malekian 2000, Zhang et al. 2017). Guillon and Champ (2000) explained that apart from the influence of processing and storage conditions, changes in fiber contents might result from the effects of chemical processes and thermos-mechanicals.

Ash contents

Ash is a measure of the total amount of minerals present within food. This study

reported ash contents of approximately 5.18% in raw chia seeds, 4.85% dried chia seeds at LTLT and 4.86% dried chia seeds at HTST. Similar findings, approximately 4.45% were reported by Kibui et al. (2018), 4.6% by Coelho and Salas-Mellado (2014) and 4 to 5% by Haripriya and Aparna (2018). Drying at low temperature long time and high temperature short time significantly ($p = 0.000$) reduced ash content compared to raw chia seeds (control). However, there was no significant difference between the two drying conditions ($p = 0.622$) (Figure). The decrease in ash contents of the dried chia seeds was not expected since minerals are generally stable to minimum and moderate heating. The slight changes that occurred in the values may be attributed to removal of carbon, hydrogen, nitrogen, oxygen chlorine and partly bromine (Harju et al. 2004).

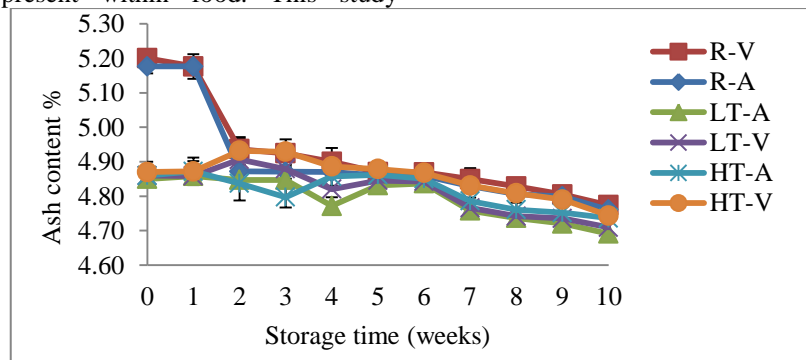


Figure 2: Changes in ash contents of chia seeds packed in air and vacuum conditions and stored at room temperature. Results expressed as means \pm standard deviation ($n = 3$).

There is also a possibility that some elements of interest were lost during the storage because a decrease in ash contents in all samples was observed. Chemical changes such as respiration of survived seed cells during heating might have decreased the levels of carbohydrates, hydrogen and oxygen and caused weight losses in the samples which subsequently decreased the ash content (Harju et al. 2004). However, the differences in ash contents of chia seeds were observed at the 5th and 10th weeks of storage ($p < 0.05$). All the

analyses revealed that the decrease in ash contents was higher in chia seeds dried at LTLT and HTST than that in raw chia seeds. Samples packed in air for all storage conditions were marked with more effects of ash reduction than those packed in vacuum. This observation tallied with the previous assertion that survived seed cells during heating respired and decreased the levels of carbohydrates, hydrogen and oxygen which subsequently lowered the ash content (Harju et al. 2004).

Fat contents

When the internal temperature of a food rises, its fats volatilize (Uribe et al. 2019). Therefore, drying volatilized fats stored in chia seeds to the extent that a difference in fat contents of dried and raw chia seeds before storage was significant ($p = 0.000$) (Figure 3). Rise in temperature as a result of drying influences fat volatility by weakening chemical bonds existing in fats molecules (Durmaz et al. 2010, Cai et al. 2013). Fat values in chia seeds dried at low temperature long time and high temperature short time before storage were not statistically different ($p = 0.683$). This signified absence of difference in instant amounts of fats released from the seeds by the two drying conditions.

Effects of drying increased fat losses during storage because the reduction in fat contents observed in raw chia seeds was lower than that in dried chia seeds. Degradation of chemical bonds that took place during drying was different and the decrease in fats was relatively higher in seeds dried at low temperature long time than that dried at high temperature short time ($p = 0.000$). On the other side, all samples packed in air had higher fat losses than those packed in vacuum (Figure 3). Air packaging expose fats to oxidations causing fat deterioration, hence the difference. However, it depends on the fatty acids and the presence of other compounds such as antioxidants (Ixtaina et al. 2012, Giurizatto et al. 2012).

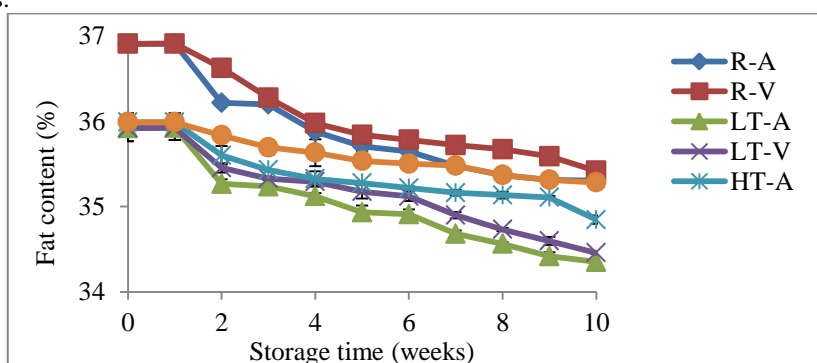


Figure 3: Changes in the fat contents of chia seeds packed in air and vacuum conditions and stored at room temperature. Results are expressed as means \pm standard deviation ($n = 3$).

Interactions existed in the effects of packaging and drying conditions ($p = 0.000$) brought diversities on how samples lost fat quantities over the period of storage. There was no significant difference ($p = 0.683$) between the fat contents of raw and dried chia seeds during the first week of storage. Effective interactions started from the 2nd week onwards where diversities were displayed. Chia seeds reported to contain a high amount of polyunsaturated fatty acids (PUFA) with a composition of more than 60% (Segura-Campos et al. 2013). Fatty acids play important roles in the oxidative stability of oils. The higher the unsaturated fatty acids, the faster the

oil can undergo an oxidation reaction (Liu and White 1992). However, apart from the presence of PUFA in chia seeds, extended storage of the seeds may result in oxidation of PUFA.

Protein contents

The results of protein for raw and dried chia seeds are presented in Table 2. There was a significant decrease ($p < 0.05$) of protein contents in all samples from 24.54 to 23.66% in R_A , 24.53 to 23.74% in R_V , 24.41 to 23.34% in LT_A , 24.39 to 23.43% in LT_V , 24.50 to 23.55% in HT_A and 24.48 to 23.64 in HT_V . Chia seeds are good sources of plant protein that accounts for 18-24% protein dry mass

(Kulczyński et al. 2019). Protein value found in raw chia seeds before storage, was 24.5% higher than 23% reported by Coelho and Salas-Mellado (2014) and 20.90% by Kibui et al. (2018). The high protein levels in the chia seeds may result from the geographical, agronomic, and environmental conditions including climate and soil.

This study revealed that proteins of raw and dried chia seeds before storage were not

significantly different ($p = 0.117$), indicating stability of chia protein to action of heat during drying. Stability of protein during drying has been reported in previous study of sliced chestnuts by Delgado et al. (2016). There was significant decrease ($p < 0.05$) in protein stability during storage. The decrease in protein was highly dependent on storage time, packaging and drying conditions.

Table 2: Protein contents of chia seeds packed in air and vacuum conditions during storage

Storage time (weeks)	R _A	R _V	LT _A	LT _V	HT _A	HT _V
0	24.5 ± 0.13 ^a	24.5 ± 0.20 ^a	24.4 ± 0.06 ^a	24.4 ± 0.04 ^a	24.5 ± 0.03 ^a	24.5 ± 0.12 ^a
1	24.5 ± 0.12 ^a	24.5 ± 0.12 ^a	24.4 ± 0.05 ^a	24.4 ± 0.05 ^a	24.5 ± 0.02 ^a	24.5 ± 0.02 ^a
2	24.4 ± 0.07 ^a	24.4 ± 0.05 ^a	24.3 ± 0.02 ^a	24.3 ± 0.06 ^a	24.4 ± 0.00 ^a	24.5 ± 0.32 ^a
3	24.3 ± 0.03 ^a	24.4 ± 0.04 ^a	24.2 ± 0.00 ^a	24.3 ± 0.05 ^a	24.3 ± 0.02 ^a	24.3 ± 0.19 ^a
4	24.3 ± 0.03 ^a	24.4 ± 0.04 ^b	24.2 ± 0.00 ^a	24.3 ± 0.05 ^a	24.3 ± 0.03 ^a	24.4 ± 0.19 ^b
5	24.2 ± 0.01 ^a	24.3 ± 0.05 ^b	24.1 ± 0.00 ^a	24.1 ± 0.00 ^a	24.2 ± 0.07 ^a	24.2 ± 0.00 ^a
6	24.2 ± 0.00 ^a	24.3 ± 0.00 ^b	23.9 ± 0.07 ^c	24.1 ± 0.02 ^d	24.0 ± 0.00 ^d	24.1 ± 0.01 ^d
7	24.1 ± 0.15 ^c	24.1 ± 0.08 ^{ac}	23.7 ± 0.16 ^a	23.8 ± 0.03 ^{ab}	23.9 ± 0.09 ^{abc}	24.0 ± 0.03 ^{bc}
8	23.9 ± 0.05 ^c	24.1 ± 0.01 ^c	23.6 ± 0.05 ^a	23.7 ± 0.05 ^{ab}	23.7 ± 0.13 ^{ab}	23.8 ± 0.16 ^b
9	23.7 ± 0.18 ^a	23.7 ± 0.02 ^a	23.3 ± 0.03 ^a	23.4 ± 0.00 ^a	23.5 ± 0.02 ^a	23.7 ± 0.06 ^a
10	23.7 ± 0.18 ^a	23.7 ± 0.02 ^a	23.3 ± 0.03 ^b	23.4 ± 0.01 ^b	23.6 ± 0.02 ^{ab}	23.6 ± 0.07 ^a

Key: Results expressed as means ± standard deviation (n = 3). Samples sharing the same superscript letters in a row for each week are not significantly different at 5% significant level according to Tukey's HSD multiple ranks test.

In the first three weeks of storage, protein in chia seeds for all conditions demonstrated similar patterns. Variations in patterns of reduction started at the 4th week where two groups emerged, LT_A, HT_A, LT_V and R_A samples ($p = 0.075$) and that in HT_V and R_V ($p = 0.060$), respectively were not statistically different. Irregular patterns in reducing protein contents continued up to the end of storage time. The differences may be due to chemical changes in protein and interactions between the effects of drying temperature and packaging conditions (Zhang et al. 2017). Over the storage period, decrease in protein was the highest in chia seeds dried at low temperature long time with more effects in samples stored in air than those in vacuum ($p = 0.071$) followed by samples dried at high temperature short time ($p = 0.287$) and the lowest was in the

control. The observed decrease in protein contents of chia seeds indicated degradation of proteins to small peptides and amino acids during the storage period (Liu et al. 2008, Lee and Cho 2012, Mhiko 2012, Zhang et al. 2017). The decrease in protein may also be due to protein destruction and denaturation during storage.

Conclusion

The effects of drying, packaging conditions and storage time on the proximate composition of chia seeds were established. Proximate composition of chia seeds was affected by drying, packaging conditions and storage time. The results of this study indicated that the chia seeds evaluated were rich in protein in comparison to the findings of previous studies. In both the drying conditions, ash, fat and

protein contents were significantly greater in vacuum than in air packaging, although the impact was vice versa for moisture and fiber contents. The high temperature short time drying condition with vacuum packaging was effective in maintaining proximate values of chia seeds. The chia seeds are recommended for use in management of protein deficiency which is endemic not only to people in Tanzania but also to people in African countries.

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