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COMPARATIVE EFFECTS OF DRYING ON THE DRYING CHARACTERISTICS, PRODUCT QUALITY AND PROXIMATE COMPOSITION OF SOME SELECTED VEGETABLES

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ABSTRACT: *This study investigated the effects of drying on the drying characteristics, product quality and proximate composition of some selected vegetables. The vegetable investigated were Ocimum gratissimum (Scent leaf), Vernonia amygdalina (Bitter leaf), Moringa oleifera and Heinsia crinite (Atama leaf). These vegetables were collected fresh, sorted, oven dried at 50°C for 12 h and evaluated for drying kinetics, rehydration properties, proximate composition, and total chlorophyll content. The result of drying kinetics indicated that the rate of moisture loss was at its highest in the first and second hour of drying; however the moisture loss was slowed down in the subsequent drying period. The removal of moisture at the end of drying was found to be at a faster rate in the following order: bitter leaf>scent leaf>Moring oleifera leaf>atama leaf. Results of the rehydration properties showed that significantly (p<0.05) higher rehydration ratio and rehydration capacity was obtained in atama leaves (10.56 and 0.223, respectively) while Moringa oleifera recorded the lowest (10.56 and 0.097, respectively). The results revealed that the drying significantly (p<0.05) affected the proximate composition of the dried vegetables with bitter leaf having the highest ash and protein content (11.31% and 29.28%, respectively), atama had the highest fat and carbohydrate content (17.36% and 50.33%, respectively) while Moringa oleifera was highest in crude fibre (19.98%). Total chlorophyll content was higher in the dried vegetables (1.75-3.22mg/100g) than in the fresh vegetable (0.80-1.39mg/100g). In its fresh and dried forms, bitter leaf had the highest chlorophyll content (1.39 and 3.22mg/100g) while chlorophyll retention was highest in scent leaf (67.21%) after drying. This study therefore indicates that drying affects the nutritional composition and product quality of the vegetables differently and that these vegetables in its dried forms are recommended as they supply adequate nutrients.*

KEYWORDS: Drying, Scent leaf, Bitter leaf, Moringa oleifera, atama leaf

INTRODUCTION

Green leafy vegetables occupy an important place among food crops as they provide adequate amounts of vitamins and minerals for humans (Vyankatrao, 2014). They are fresh agricultural produce having high moisture content and characterized as highly perishable in nature. They also occupy a vital place in diet because of their colour, flavor, nutrient content and health benefits.

According to Negi and Roy (2000), these vegetables serve as rich sources of β-carotene, ascorbic acid, iron, zinc, folate and dietary fibre. They are usually consumed as cooked complements to major staples like cassava, rice, plantain and maize and also used in the preparation of soups and sauces in Africa. Some are consumed raw, some eaten cooked in order to be edible while others are dried for shelf-life extension.

Drying is an important step in maintaining the quality, nutritional value and shelf-life extension of vegetables (Chemkhi *et al*., 2004). When vegetables are properly dried, they are less susceptible to spoilage caused by the growth of bacteria, molds and insects (Adeleye, 2018). Plants respond differently to drying. The effect of drying on plants will depend on the initial moisture content of the product and this varies with the type of vegetable to be dried. Mu'azu *et al*. (2016) carried out a study of drying characteristics of some selected vegetables (okra, onion, red pepper and tomato). It was observed that tomato had maximum average drying rate of 1.23 kg/hr and onion had the least (0.77 kg/hr). The effect of drying on the qualities of some selected vegetables was also studied by Awogbemi and Ogunleye (2009) and it was observed that *Vernonia* spp (ewuro) had the highest drying rate, followed by *Amarantus* spp (Tete) and fluted pumpkin (ugu). It is evident that the changes in moisture content as a function of time will characterize the drying behavior of the vegetables to be studied. The drying characteristic of each vegetable is intrinsic and so will behave uniquely during drying (Guine and Fernandes, 2006) which is why there is a need to investigate the comparative effect of drying on the drying characteristics and nutrient constituents of some common edible leafy vegetables in the country The objective of this work therefore is to determine the effect of drying on the drying characteristics, product quality and proximate composition of some selected vegetables in order to serve as a guide for industrialist and nutritionist in understanding the drying behaviours of these vegetables so as to maximize nutrient retention.

MATERIALS/METHODS

Collection of Vegetables

The leafy vegetables used in this study include bitter leaf (*Vernonia* species), *moringa oleifera* leaf, scent leaf (*Ocimum gratissimum*) and atama leaf (*Hensia crinte*). *Moringa oleifera* leaves were obtained from Dilomat farms in Rivers State University, Port Harcourt while the other vegetables were obtained from Mile 3 market, Port Harcourt, Rivers State, Nigeria. These vegetables were collected fresh and sorted in order to remove those that were injured either by insect or during the period of collection, those that were decayed or wilted and those that were discoloured.

Chemicals
All the chemicals used in this study were of analytical grade. They were obtained from Department of Food Science and Technology, Rivers State University, Port Harcourt, Nigeria.

Drying Procedure
Two hundred (200g) of each sample was washed in ordinary tap water. The vegetables were oven dried at 50°C for 12h. They were cooled in a desiccator and stored in an airtight container for proximate analysis, rehydration capacity and total chlorophyll content.

Proximate Analysis
Moisture, ash, crude protein, fat, and crude fibre contents of the dried vegetables were determined using the AOAC (2012) method while carbohydrate content was determined by difference.

Determination of Total Chlorophyll content
The method described by Manolopoulou *et al*. (2016) was used for determination of total chlorophyll content. Chlorophyll extraction was carried out with a mixture of acetone and water at a ratio of 80% -20% (v/v). Two grams (2.0g) of the vegetable was homogenized with 25 ml of 80% acetone solution using a laboratory blender for 2 min. Filtration was followed and the filtrate transferred to a volumetric flask of 100 ml covered with aluminum foil to avoid oxidation of chlorophyll from light and filled to the top with acetone solution 80%. Absorption was measured at 663 and 645 nm using a spectrophotometer. Concentration of total chlorophyll was expressed as mg /g fresh weight. Determination of chlorophyll total chlorophyll was carried out using the formula;

Total chlorophyll (mg/g fresh weight) = $(20.2\, A_{645} + 8.02\, A_{663}) \times \frac{X}{1000} \times n$

Where: A_{645}= absorption value at 645 nm
A_{663}= absorption value at 663 nm
X = total volume of filtrate
n = tissue weight.

Drying Kinetics
The method of Ahmed *et al*. (2001) was used for drying kinetics. The leaves were dried on perforated trays in an air oven at 50°C. An approximately 5g sample of each sample was placed in a metal can. The samples were withdrawn at hourly intervals and measured using a digital weighing machine to monitor weight reduction due to loss of moisture in the samples. The percentage moisture contents (%MC) of the samples at various drying time on dry basis was obtained from the expression.

$$\%MC = \frac{Mi - Md}{Md} \times 100$$

$$\text{Drying rate (DR)} = \frac{Mi - Md}{t}$$

Where;
M_i = Mass of the sample at time i
M_d = mass of the dry solid

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t= time

2.7. Rehydration Ratio (*RR*)

The rehydration ratio and capacity was used as a quality characteristic of the dried product (Velić *et al.* 2004). Approximately 2.0g of the dried vegetable sample was placed in a 250 ml laboratory glass thereafter 150 ml distilled water was added and the glass was covered and heated to boil within 3 minutes. The content of the laboratory glass was then gently boiled for 10 more min and then cooled. The cooled content was filtered for 5 min and weighed. The rehydration ratio and capacity was calculated as:

$$RR = \frac{Weight\ of\ rehydrated\ material}{\text{Weight of dehydrated material}}$$

$$\text{RC} = \frac{Regained\ moisture\ (g)}{Initial\ moisture\ (g) - Residual\ moisture\ (g)}$$

Statistical Analysis

Experimental data were analyzed using analysis of variance (ANOVA) and significant differences among means at $p<0.05$ were determined by Duncan's multiple range test (DMRT) using the Statistical Package for Social Science (SPSS) version 20.0.

RESULT/DISCUSSIONS

Drying Behaviour of Selected Vegetables

The drying kinetics of selected vegetables is presented in Fig 1 and 2. The result of the drying behavior of selected vegetables showed that there was a general decline in the moisture content of the vegetables from 66.00-13.37% for bitter leaves, scent leaf 69.18-15.97%, *Moringa oleifera* leaves 77.69-18.56% and atama leaves 63.62-24.40%. The result also indicated that the rate of moisture loss was at its highest in the first and second hour of drying; however the moisture loss was slowed down in the subsequent drying period. Similar trend was also observed by Papu *et al.* (2014) who reported a faster drying rate for amaranth leaves after 1 hour. Among the vegetables, the removal of moisture at the end of drying was found to be at a faster rate in the following order: bitter leaf>scent leaf>*Moring oleifera* leaf>atama leaf. This can be attributed to the initial moisture content of the vegetables as they were not the same. The actual amount of water present in a given material will influence how fast it may be dried to a desired final moisture level. According to Donald (2014), it will take longer time to dry a vegetable with higher moisture content than it will for other vegetables with slightly lower moisture content.

The presence of constant rate period can also be seen from the drying rate curve for all the vegetables. The duration of the constant rate period of these vegetables were from 6-7 hours of drying time. Higher drying rates in the beginning (0-6h) were due to presence of excessive moisture on the surface of the vegetables. Mahesh *et al*. (2017) also observed similar drying rates for some selected vegetables of Punjab, India to decrease sharply in the first six hours where majority of water removed. A stable weight was reached faster in bitter leaves (0.01kg/hr) compared for scent leaf (0.11kg/h), atama leaves (3.20-0.17kg/h) and *Moringa oleifera* leaves

(3.90-0.13kg/h). This is due to the differences in the initial moisture content of the vegetables. This is in correlation with the study of Mu'azu *et al*. (2016) who observed that tomato had maximum drying rate of 1.23kg/hr as compared to onion (0.77kg/hr) owing to the initial moisture content and surface area of these vegetables. Guine (2018) reported that the drying rate is influenced by transfer mechanisms, such as the vapour pressures of the vegetable and of the drying air, temperature and air velocity, moisture diffusion in the product, thickness and surface exposed for drying.

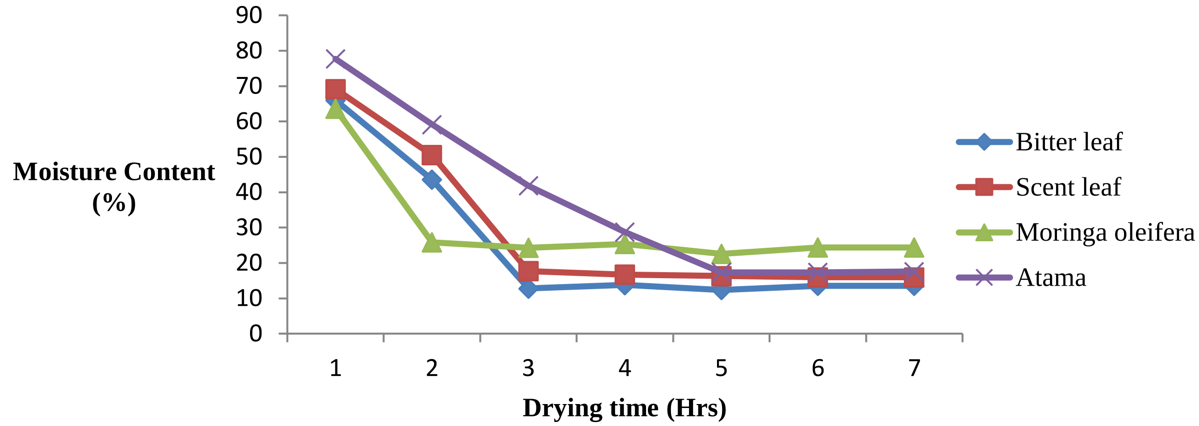

Fig 1: Variation of moisture content with drying time for the selected vegetables

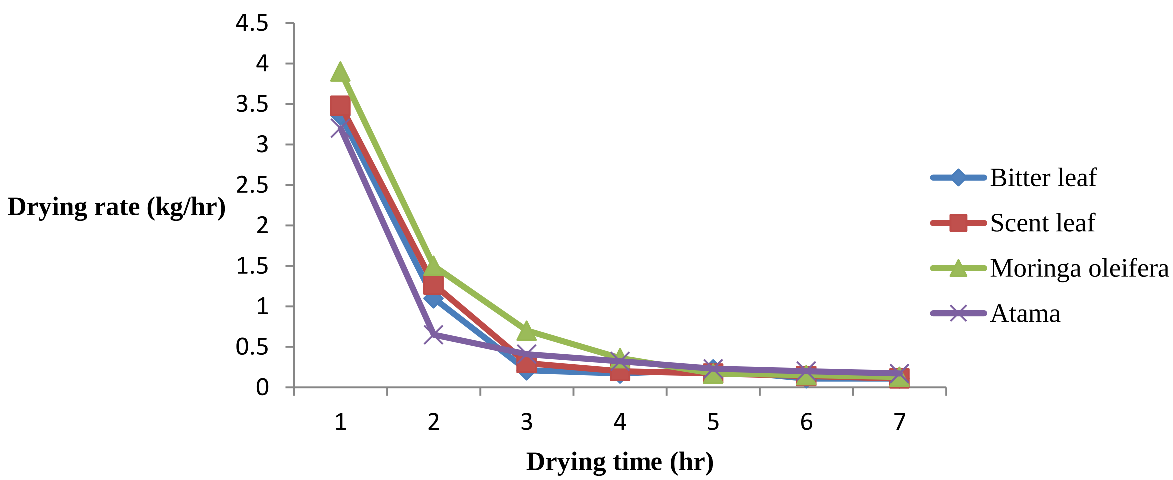

Fig 2: Variation of drying rate with drying time for the selected vegetables

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Effect of Drying on the Rehydration Properties of the Selected Vegetables

The rehydration properties of the selected vegetables are shown in Fig 3. Rehydration refers to the process of moistening a dried product and is an indicator of quality criterion in most dried foods. It is an indicator of cellular and structural disintegration that occurs during dehydration (Rastogi *et al*., 2000). The ability of food products to reconstitute depends on primarily the internal structure of the dried pieces and the extent to which the water holding components (e.g. proteins) has been damaged during drying (Krokida and Philippopoulos, 2005). The lowest rehydration ratio value was 5.20 for *Moringa oleifera* leaves. This value was significantly ($p<0.05$) different from all other samples. This could be explained to be due to cellular structure damage resulting in modifications of osmotic properties of the cell as well as lower diffusion of water through the surface during rehydration (Kaymak-Ertekin, 2002). Higher rehydration ratio indicates better dried product and this was observed in Atama leaves with rehydration ratio of 10.56. Higher rehydration ratio obtained from this study may possibly be due to minimum changes in the structure of protein and consequently minimum changes in protein functionality (Jayathunge and Illeperuma, 2001).

The rehydration capacity of the rehydrated vegetables ranged from 0.097-0.223 with atama leaves having higher rehydration capacity and significantly ($p<0.05$) different from other vegetables. *Moringa oleifera* had the lowest rehydration capacity and the lower rehydration capacity values for *moringa oleifera* leaves may probably be due to cellular break down of the product during drying. The rehydration capacity values for these vegetables (except atama leaves) were lower than that for coriander leaves (0.201) as reported by Ahmed *et al*. (2011). The rehydration capacity of the dried samples is important to consumers and food technologist. Properties such as the rehydration capacity of the rehydrated samples are more important, especially if these vegetables are used, for example, in instant soup (Jokic *et al*., 2009).

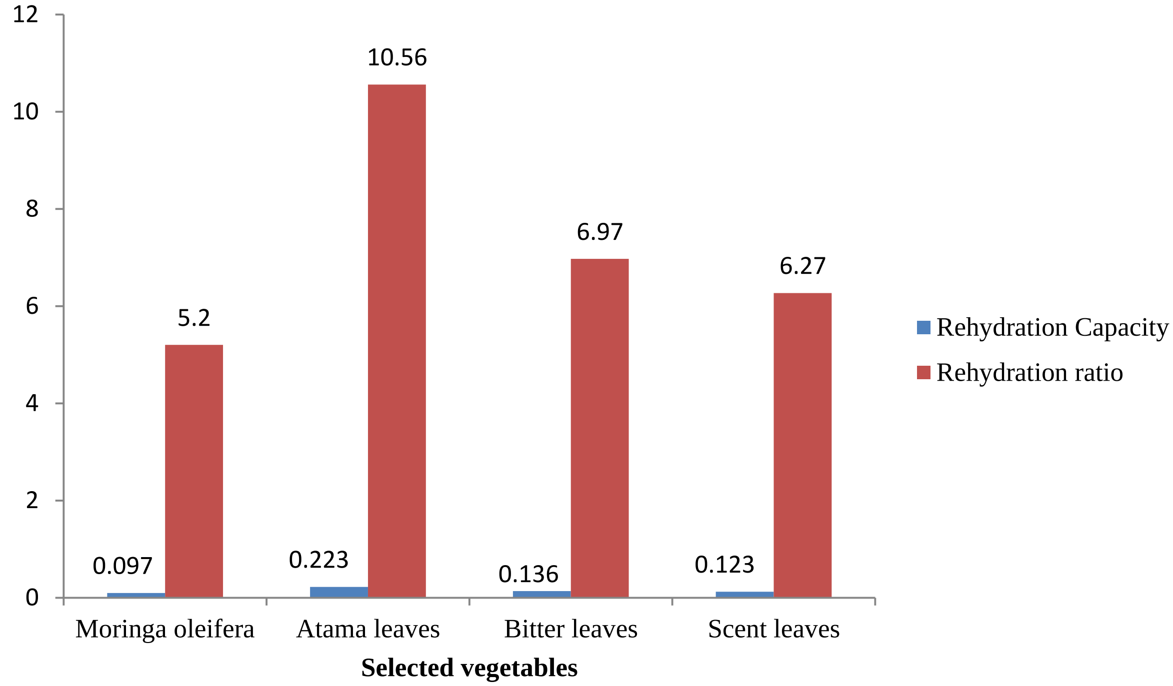

Fig 3: Rehydration properties of the selected vegetables

Proximate Composition of the Dried Vegetables

Proximate composition of the dried vegetables is presented in Table 1. The moisture content of the dried vegetables was 6.22, 5.48, 5.73 and 5.47% for bitter leaves, atama, scent and *Moringa oleifera* leaves, respectively. There was no significant ($p>0.05$) difference in their moisture content. The maximum moisture content varies between individual vegetables because of their structural differences (Florkowski *et al*., 2009). The moisture content of the dried vegetables studies was low when compared to that of dried cauliflower (9.99%) reported by Baloch *et al*. (2015) and sundried broccoli (7.29%) reported by Kaur *et al*. (2008). Moisture content of food is very important for shelf-life determination and any food prepared from dried leafy vegetables has more keeping quality than the fresh ones (Chou and Chua, 2001).

Ash content of the dried bitter leaves (11.31%) and scent leaves (11.07%) were significantly ($p<0.05$) higher than that of atama leaves (9.41%) and *Moringa oleifera* leaves (10.46%). These values were high when compared to the ash content of shade dried *H. sabdariffa* (3.27%) and *A. hybridus* (22.66%) as reported by Oulai *et al*. (2016). It was also higher than the ash content of dried cauliflower (5.98%) as reported by Baloch *et al*. (2015). Ash content in food is an indication of the presence of minerals and dried bitter leaves and scent leaves could be considered as valuable sources of minerals for alleviating micronutrient deficiency related to minerals in human nutrition. Protein content of the dried vegetables was 18.88, 27.21, 29.28 and 25.01% for atama, scent leaf, bitter leaf and *Moringa oleifera* leaf, respectively. Dried bitter leaf had protein content significantly higher ($p<0.05$) than other vegetables except for bitter leaves while dried atama had the least protein content. These results are higher than the protein content of oven dried *T. occidentalis* (9.63%), *T. triangulare* (2.90%) and *A. hybridus* (7.57%) as reported by Oni *et al*. (2015). The protein content of *Moringa oleifera* obtained from this study (25.01%) agrees with the result of Alakali *et al*. (2015) for oven dried *Moringa oleifera* leaves (26.24%). Protein is an essential component of human diet needed for the replacement of tissue and for the supply of energy and adequate amount of required amino acid. Protein deficiency causes growth retardation, muscle wasting, oedema, abnormal swelling of the body and collection of fluid in the body of children (Mounts, 2000).

Fat content ranged from 9.17-17.36% with dried atama recording significantly higher ($p<0.05$) fat content while no significant difference ($p>0.05$) was recorded in the fat content of dried *Moringa oleifera*, bitter and scent leaves. These results are higher than the fat content of oven dried *T. occidentalis* (2.41%), *T. triangulare* (0.53%) and *A. hybridus* (1.92%) as reported by Oni *et al*. (2015). It is also higher than the fat content of vacuum oven dried *Ocimum basilicum* leaves (5.86%) reported by Siti *et al*. (2018). The fat content of dried *Moringa oleifera* leaves (10.20%) is close to the fat content of oven dried *Moringa oleifera* (9.12%) reported by Emelike and Ebere (2016).

Crude fibre content of the dried vegetables was 19.98, 22.60, 16.23 and 24.55% for bitter leaf, atama leaf, scent leaf and *Moringa oleifera*, respectively. Fibre content of *Moringa oleifera* was significantly higher ($p<0.05$) than other dried vegetables except for atama leaf. Crude fibre content of the dried vegetables studied was higher than *T. triangulare* (0.93%) and *T. occidentalis* (2.94%) as reported by Oni *et al*. (2015). The fibre content of *M. oleifera* obtained from this study is higher than that of Alakali *et al*. (2015) as 17.66% for oven dried *Moringa oleifera*. Fiber aids and speeds up the excretion of waste and toxins from the body preventing them from sitting in the intestine or bowel for too long, which could cause a buildup and lead to several diseases (Hunt *et al*., 1980).
Carbohydrate content for the dried vegetables was 44.02, 56.33, 50.66 and 47.1% for dried bitter leaf, atama leaf, scent leaf and *Moringa oleifera*, respectively. Carbohydrate content of the dried atama differed significantly ($p<0.05$) from others while that of scent leaf and *Moringa oleifera* showed no significant difference ($p>0.05$) . Carbohydrate content of the dried vegetables in this study is higher than dried cauliflower (42.44%) as reported by Baloch *et al*. (2015). Emelike *et al*. (2015) also reported 29.32% for oven dried *Moringa oleifera* which is far lower than the carbohydrate content of *Moringa oleifera* obtained from this study. The carbohydrate content of dried *Moringa oleifera* from this study also agrees with that of Alkali *et al*. (2015) as 46.34% for oven dried *Moringa oleifera.*

Table 1: Proximate composition of the dried vegetables

Samples	Moisture (%)	Ash (%)	Fat (%)	Crude protein (%)	Crude fibre (%)	CHO (%)
Bitter leaf	6.22[a]±1.02	11.31[a]±0.43	9.17[b]±0.28	29.28[a]±1.23	19.98[b]±1.44	44.02[c]±2.40
Atama leaf	5.48[a]±0.39	9.41[b]±0.76	17.36[a]±1.93	11.88[c]±2.47	22.60[ab]±0.56	56.33[a]±1.01
Scent leaf	5.73[a]±0.14	11.07[a]±0.11	7.53[b]±0.06	27.21[ab]±0.62	16.23[c]±1.09	50.66[b]±0.21
Moringa oleifera	5.47[a]±0.25	10.46[b]±0.18	10.20[b]±0.01	25.01[b]±0.18	24.55[a]±0.23	47.71[b]±0.10

Values are expressed as mean ± standard deviation of duplicate determination. Means with the same letters along the same column are not significantly different ($p>0.05$).

Effect of Drying on the Total Chlorophyll of the Selected Vegetables

Total chlorophyll content of the fresh and dried vegetables is presented in Table 2. The total chlorophyll content of the vegetables was 0.82, 1.13, 1.39 and 0.80mg/100g for fresh atama, Moringa, bitter leaves and scent leaves, respectively. For the dried vegetables, the total chlorophyll contents were 1.75, 1.76, 3.22 and 2.44mg/100g for dried atama, moringa, bitter and scent leaves, respectively. There was a significant ($p<0.05$) difference in the total chlorophyll content of fresh moringa and bitter leaves, however, fresh atama and scent leaves showed no significant ($p>0.05$) difference in total chlorophyll contents. For dried vegetables, bitter leaves had the highest total chlorophyll content and differed significantly ($p<0.05$) from other vegetables. The chlorophyll content was higher in the dried vegetables than the fresh. The total chlorophyll content of dried bitter leaves (3.22mg/100g) were higher when compared to that of dried colocasia leaves (2.09mg/100g) as reported by Kaushal *et al*. (2013). Mahanom *et al*. (1999) also reported total chlorophyll of 1.23mg/100g and 0.44mg/100g for fresh and dried herbal tea leaves, respectively. This indicates a high potential for the acceptability of the dried vegetables because chlorophyll are desired by consumers in the green state.

Chlorophyll is a group of compounds responsible for colour (such as green) intensity of plants (Rubinskiene *et al*., 2015). The results show that drying has a significant impact on chlorophyll retention, however, the level of retention varied for each of the vegetable. The retention of chlorophyll was found to be greatest in scent leaves (67.21%) followed by bitter leaves (56.83%), atama (53.14%) and *Moringa oleifera* (35.80%).

Table 2: Total Chlorophyll content of the fresh and dried vegetables

Samples	Fresh Vegetable	Dried vegetable	Chlorophyll Retention (%)
Atama	$0.82^{c}\pm0.00$	$1.75^{c}\pm0.00$	53.14
Moringa oleifera	$1.13^{b}\pm0.02$	$1.76^{c}\pm0.01$	35.80
Bitter leaf	$1.39^{a}\pm0.01$	$3.22^{a}\pm0.01$	56.83
Scent leaf	$0.80^{c}\pm0.01$	$2.44^{b}\pm0.00$	67.21

Values are expressed as mean ± standard deviation of duplicate determination. Means with the same letters along the same column are not significantly different (p>0.05).

CONCLUSION

From the present study, it can be concluded that the dried vegetable studied contain appreciable quantities of ash, fat, crude protein, crude fibre and carbohydrate thereby contributing to nutritional value. The dried vegetables also contain low moisture levels therefore they can be stored over long periods. The dried bitter leaf and scent leaf are better sources of ash and crude protein since they contained relatively high amount of protein than others. The fat and carbohydrate content was found to be higher in atama leaf while fibre was highest in *Moringa oleifera*. The dried vegetables had higher total chlorophyll content than fresh samples with dried and fresh bitter leaf containing significantly ($p<0.05$) higher total chlorophyll content than others. The result also indicated that loss of moisture was highest in the first hour of drying and that the reduction in moisture content for atama leaf during first hour was at a higher rate than for other vegetables. A stable weight was reached faster in bitter leaf compared to others while higher rehydration ratio and capacity was observed with atama leaf which differed significantly ($p<0.05$) from all others. The consumption of the analyzed vegetables in its dried forms is recommended as they supply adequate nutrients needed for metabolic processes and maintenance of life.

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