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Proximate Composition, Physiological Changes during Storage, and Shelf Life of Some Nigerian Varieties of Yams (*Dioscorea* species)

C. Ogbo Frank[1*] and C. Agu Kingsley[1]

[1]Department of Applied Microbiology and Brewing, Nnamdi Azikiwe University, PMB 5025, Awka, Nigeria.

Authors' contributions

This work was carried out in collaboration between both authors. Author COF designed the study, wrote the protocol, and wrote the first draft of the manuscript. Author CAK managed the literature searches, performed the experimental process and all analyses including spectroscopy. Author COF identified the species of yams. Both authors read and approved the final manuscript.

Original Research Article

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ABSTRACT

Aims: The objectives of this work were to study the influence of proximate composition and physiological changes during storage, on the shelf life some *Dioscorea* sp. This is needed to complement knowledge of the influence of extrinsic factors of the storage environment in improving the shelf life, a key attribute of yam quality.
Place and Duration of Study: Department of Applied Microbiology & Brewing, Nnamdi Azikiwe University, Awka, Nigeria between January 2012 and July 2013.
Methods: AOAC and sensory methods were used to determine proximate composition and shelf life respectively, while physiological changes during storage were monitored by moisture and pH measurements.
Results: Moisture content of yams ranged from 61 - 70%; protein, 0.48 – 1%; fat, 0.39 – 1.67% and carbohydrates, 24 – 32%. These contents varied among the yams at the varietal level. Ash ranged from 1.33 – 2.17% and crude fibre, 2.83 – 4.33% and were largely similar in all varieties. During storage, different varieties of yams maintained different contents of moisture (%) but all shared similar characteristics in respiratory activity. Methanolic extracts from the peels of some *Dioscorea dumentorum* and *D*.

**Corresponding author: E-mail: frankogbo@yahoo.com;*

rotundata varieties inhibited the growth of *Aspergillus* sp. The shelf life of the yams ranged from low 27 weeks in *D. alata* to a high of 40 weeks in *D. rotundata.* Moisture content (P = 0.1) was negatively correlated while fat (P = .05) and carbohydrate contents were positively correlated with shelf life of yams.

Conclusion: The chemical composition of yams plays a role in the determination of their shelf lives. A better understanding of this relationship will help in efforts to increase yam production through the reduction of post harvest losses.

Keywords: Yams; proximate composition; physiological changes; shelf life.

1. INTRODUCTION

Yam (*Dioscorea* sp.) constitutes a staple food crop for over 100 million people in Africa, Latin America and Asia. Over 90 % of world yam production occurs in the yam belt of West and Central Africa with Nigeria alone accounting for about 68 percent of the world's total [1]. Yams are an excellent source of carbohydrate, energy, vitamins (especially vitamin C), minerals and protein. Compared to about 1% in cassava, some cultivars of yam tuber have been found to contain protein levels of 3.2 – 13.9% of dry weight [2]. Apart from its importance as a food source, yams also play important socio-cultural and economic roles among the populations of these regions. Thus, yams serve as indices of wealth and are obligatory components of the practice of traditional ceremonies and religions.

Major hindrances to the production of yams include the high cost of storing harvested yams. Apart from infrastructural costs, post harvest losses of yams during storage, which could be as high as 50 % (actual figures are not available) under certain conditions, represents a significant cost. Considerable research effort has been expended on the development of improved storage methods for yams as has been reviewed by FAO [3]. However, these new methods have failed to gain acceptance and farmers continue to use the traditional yam barn [2], as the principal method of storage. This is because in addition to socio-cultural attachments to the yam tuber form, there is also a low acceptability for processed and more stable forms of yam such as flour and flakes among local populations of West Africa.

Because yams are preferred in their fresh tuber form, the attribute of shelf life is very important to farmers. They therefore seek to maintain a balance between this and other important attributes such as yield, nutrition and organoleptic attributes among others, in the choice of yam varieties to cultivate. Shelf life is the length of time that a commodity may be stored without becoming unfit for use or consumption (Oxford English Dictionary, 2nd ed.). The shelf life of yam is influenced by two major factors. First is its dormancy period, during which the tuber retains all its food quality characteristics. The breaking of dormancy is signaled by sprouting. This also signals the commencement of physiological changes within the tuber arising from sprouting and respiration, which lead to the loss of food quality characteristics [4]. The second factor involves the efficiency of storage techniques in controlling the rate of these physiological changes as well as rots due to microbial activity. The extrinsic factors of the storage environment, mainly temperature and relative humidity influencing these physiological changes are well understood [5]. There is no knowledge however, about the role, if any, of the chemical nature or the intrinsic characteristics of the tuber itself.

The objectives of this work are therefore to study the proximate composition and physiological changes during the storage of some varieties of *Dioscorea* sp., cultivated in the Eastern region of Nigeria and to determine whether these properties have a correlation with their shelf lives. Results from our research will provide data about shelf life of yams, and in the short term, provide local farmers with advice about choice of varieties for cultivation. In the long term, it will contribute data for development of improved storage procedures as well as the genetic improvement of yam keeping quality.

2. MATERIALS AND METHODS

2.1 Yam Samples

Five varieties of yams cultivated in the Eastern parts of Nigeria were used in this study. The yams and their local names, used to denote their varieties in this paper were; *Dioscorea dumentorum*, also called trifoliate yam (var. ona), *Dioscorea alata* also called water yam (var. abana mmee), *Dioscorea alata* (var. abana ocha), *Dioscorea rotundata* also called Guinea yam (var. adaka) and *Dioscorea rotundata* (var. abi). Sixty tubers of each variety were obtained from farmers in Agwbu, Orumba North Local Government of Anambra State, Nigeria about two weeks after their harvest. Yams were selected on the basis of their good health, absence of cuts on their skin and fair uniformity in weight.

2.2 Proximate Analyses

Ten tubers of each variety of yam was prepared into samples as appropriate and subjected to proximate analyses using routine methods as described by the Association of Official analytical Chemists [6].

2.3 Determination of Antifungal Activity of Peel and Pulp of Yams

The peels of some tubers of yams have been reported to contain antimicrobial substances, which may assist in warding off microbial infection. The presence of these substances in the varieties of yams studied was determined using the agar well diffusion method on Sabouraud's dextrose agar using the methods described by Perez et al. [7]. Extracts used were obtained by Soxhlet extraction in methanol, hexane and water. The test organisms were *Aspergillus flavus*, *Lasiodiplodia theobromae, Aspergillus tamari,* and *Fusarium solani*, isolated in a previous study from decaying yams and identified at CABI E-UK, Bakeham Lane, Egham, Surrey, TW20 9TY, England, UK. Extent of inhibition of microbial activity was estimated by measurement of inhibition zones (mm).

2.4 Determination of Shelf Life of Yams

For the determination of shelf life of yams, 50 tubers of each variety were stored in a partially shaded experimental yam barn, consisting of separate wooden shelves [8]. The barn was well ventilated and protected from insect pests using wire netting. Temperature and relative humidity of the barn were averages of 30°C and 95% RH respectively, during the period of storage. Yams were de-sprouted on observation and those showing symptoms of microbial spoilage were discarded. Yams were deemed to have reached the end of their shelf lives when they became shriveled and cooked samples became unacceptable to tasters accustomed to yam meals using acceptance tests on the 7 point hedonic scale. The number of weeks taken by each variety to attain this was recorded as its shelf life. The ratio of the number of yams discarded due to microbial spoilage compared to total number of yams stored were used to calculate percentage spoilage rate.

2.5 Estimation of Physiological Changes within the Tuber during Storage

Physiological changes within the tuber, which determine the shelf life of yams primarily, arise from sprouting, transpiration and respiration. During this study, the effect of sprouting was minimized by de-sprouting. The effects of transpiration and respiration were then estimated by the easily measurable parameters of moisture and pH of the stored tubers. Measurements were taken bi-weekly during the period of storage.

2.6 Statistical Analyses

All measurements were carried out in triplicate and data subjected to Analyses of Variance (ANOVA) and Pearson's Correlation coefficient analyses as appropriate.

3. RESULTS AND DISCUSSION

3.1 Proximate Composition of Yams

The proximate composition of the varieties studied (Table 1), generally fall within the ranges described by Knoth [2] for these species of yams and in agreement with more recent reports [9;10;11;12]. The moisture content of the yams ranged from 62 – 69 %, with the *Dioscorea alata* varieties containing the highest and the *Dioscorea rotundata*, the lowest. Species similarity was observed only among the *D. alata* varieties while all other varieties differed significantly from one another (P = 0.05). The protein content of the yam varieties differed significantly from one another (P = 0.05), with var. abana mmee and var. ona showing the highest and lowest concentrations respectively.

Table 1. Mean proximate composition of different yam samples

Proximate composition (%)	***Dioscorea dumentorum*** (var. ona)	***Dioscorea alata*** (var. abana mmee)	***Dioscorea alata*** (var. abana ocha)	***Dioscorea rotundata*** (var. adaka)	***Dioscorea rotundata*** (var. abi)
Moisture	64.33±0.577^{a}	69.67±0.577^{b}	68.67± 0.577^{b}	60.70±0.608^{c}	62.67±0.577^{d}
Protein	0.19±0.006^{a}	1.05±0.017^{b}	0.79±0.035^{c}	0.67±0.040^{d}	0.48±0.069^{e}
Nitrogen	0.03±0.001^{a}	0.17±0.006^{b}	0.12±0.012^{c}	0.11± 0.006^{c}	0.08±0.017^{d}
Fat	0.40±0.01^{a}	0.39±0.032^{a}	1.0±0.2^{b}	1.13±0.115^{b}	1.67±0.115^{c}
Crude fibre	3.83±0.764^{a}	3.50±0.50^{a}	3.0±0.50^{a}	4.33±0.577^{a}	2.83±0.764^{a}
Ash	2.17±0.289^{a}	1.17±0.289^{b}	1.33±0.289^{ab}	1.17±0.288^{b}	2.0±0.50^{ab}
Carbohydrate	29.08±1.04^{a}	24.25±0.618^{b}	25.04±0.688^{b}	32.03±0.887^{c}	30.35±0.666^{a}

Means with different suffixes are significantly different at P = 0.05

The yams contained different percentage concentrations of fat (P = 0.05), which was not consistent with either species or varietal classification. Var. abana mmee had the lowest concentration of fat while var. abi had the highest. The carbohydrate content of the yams were low (24 - 25 %) and insignificantly different in the *D. alata* varieties. The *D. rotundata* varieties contained higher levels (32.03 and 30.35 %) and differed from one another significantly (P = 0.05). There were no significant differences between the fibre content of the tubers. Similarly, only the var. ona variety recorded a significant difference in mineral composition from all other varieties studied.

3.2 Antifungal Activity of Peel and Pulp of Yams

Only the extracts in methanol of the peels of var. abi and var. ona demonstrated some antifungal activity. These extracts demonstrated activity against both *Aspergillus* species used as test fungi (Table 2). Similar activities had been demonstrated by Aderiye *et al.* [13] using extracts of *Dioscorea alata* peel against *Fusarium moniliforme* and Adeleye and Ikotun [14], against some fungi including, *F. moniliforme* and *Botryodiplodia theobromae* using extracts of *Dioscorea bulbifera* L. The active compounds identified in the extracts used by these authors were β-sitosterol and dihydrodioscorine, respectively. The active compounds in the extracts used in this study have not been identified. However, the lack of activity in hexane and water extracts suggests that this compound may probably be polar in nature.

Table 2. Mean diameter (mm), zone of inhibition of growth of molds by methanolic extracts of yam peels

Test Fungi	Nystatin	Water	Var. abi	Var. ona
Aspergillus flavus	35±1.41	0	17± 1.41	6±1.4
Fusarium solani	30±0	0	0	0
Lasiodiplodia theobromae	32±1.41	0	0	0
Aspergillus tamari	33±1.41	0	13±1.41	0

3.3 Shelf Life of Yams

The shelf life of yams studied varied between species and even varieties. Varieties abi and abana mmee showed the longest and shortest mean shelf lives respectively and in reverse order, also demonstrated the highest and lowest percentage spoilage rate due to microbial activity (Table 3). Data from experimental tests for the shelf life of yams are not available for the comparison of our results. However, the shelf life of yam is known to vary greatly between species and even between cultivars, with the best keeping cultivars found among the *D. rotundata* [4]. This author further explained that the shelf life of yam derives from its dormancy period, the length of which is also both species and varietal characteristic.

Table 3. Mean shelf life of yams and percentage spoilage rate due to microbes

	***Dioscorea dumentorum* (var. ona)**	***Dioscorea alata* (var. abana mmee)**	***Dioscorea alata* (var. abana ocha)**	***Dioscorea rotundata* (var. adaka)**	***Dioscorea rotundata* (var. abi)**
Mean shelf life of yams (weeks)	31.12 ± 1.35^{a}	26.83 ± 1.74^{b}	31.64 ± 1.28^{a}	35.93 ± 1.24^{c}	39.73 ± 1.34^{d}
% spoilage rate due to microbial activity	16.7	37.5	13.3	15.0	11.1

Means with different suffixes are significantly different at P = 0.05

3.4 Physiological Changes within the Tuber during Storage

Water loss from the yam tuber by transpiration is an important physical change that occurs in the tuber during storage. This phenomenon, which has been severally reported [5,15], is significant because among other effects, it leads to the shriveling and loss of the culinary quality of the tuber. Fig. 1 reveals the time course of moisture loss from the yam tuber during storage. All the yam varieties rapidly lost moisture within the first 10 weeks of storage, but subsequently, appeared to remain stable at their different levels until the end of the study. All the varieties of yam lost moisture at the same rate because transpiration is essentially a physical evaporation process [5]. The tubers irrespective of variety tended to establish equilibrium between water vapour pressure of the surrounding air and the tubers. Transpiration is controlled by the environmental factors of temperature, relative humidity and the rate of air movement surrounding the tuber [4,16].

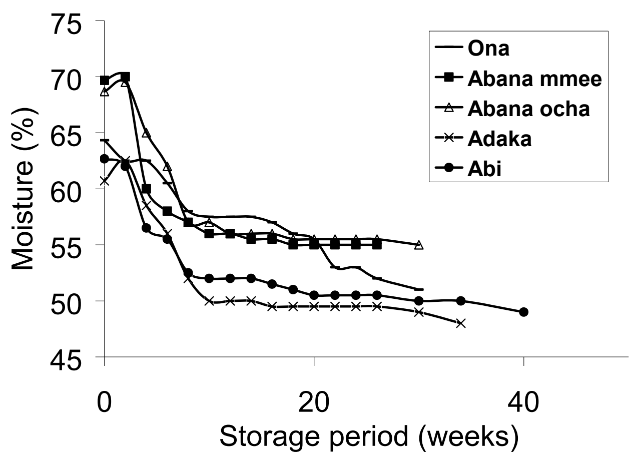

Fig. 1. Changes in moisture composition of yams during storage

The yams however, maintained different levels of moisture during the stable period. This may be related to the different water binding capacities and chemistry of the starch molecules in the different tubers. *D. rotundata* starch has a high swelling power, low amylose and water binding capacity compared with *D. alata* starch, which has a high amylose, water binding capacity and low swelling power [17].

Perhaps, the most prominent physiological change occurring in the tuber during storage is respiration. This leads to the loss of dry matter and quality of the tuber as food [4,16]. Except for *Dioscorea dumentorum,* with a slightly lower value, all other varieties studied showed similarity in their pH at the commencement of storage. Fig. 2 reveals a period of minimal chemical change in pH of the tubers within the first 15 weeks of storage, corresponding to the dormancy period. This is followed by a rise in pH coincidental with the breaking of dormancy and hence the commencement of reactions associated with respiration. Respiration is accompanied by losses of CO_2 and H_2O from the tuber. Both these molecules are associated with acidity and their loss from the tuber may explain the increase in pH of the tubers following the breaking of dormancy. The pH of tubers appears to stop their increase about five weeks after the commencement of dormancy and to remain steady until the end of this study. This observation may be associated with the attainment of maximal rates of respiration as well as poising capacities of the tubers. The time course of pH change is similar in all varieties of yam studied. Respiration has a similar mechanism in all living things.

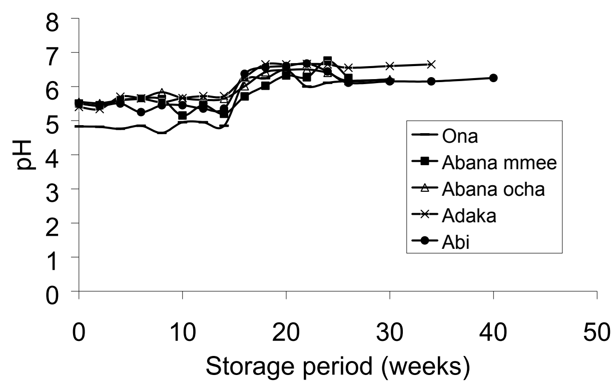

Fig. 2. Changes in pH during the storage of yams

3.5 Correlation between Proximate Composition and Shelf Life

Relatively high contents of moisture both at commencement and during the storage period probably had a role in the rate of susceptibility to microbial attack observed among the yam varieties. Thus, var. abana mmee with the highest moisture composition suffered the highest rate of susceptibility to microbial attack observed. There was a significant negative correlation (*P* = 0.1), between moisture content and the shelf life of yams studied (Fig. 3). Both the physiological and microbial activities involved in the deterioration of yams involve chemical reactions, which require water. Higher content of water during storage therefore encouraged a higher rate of these reactions.

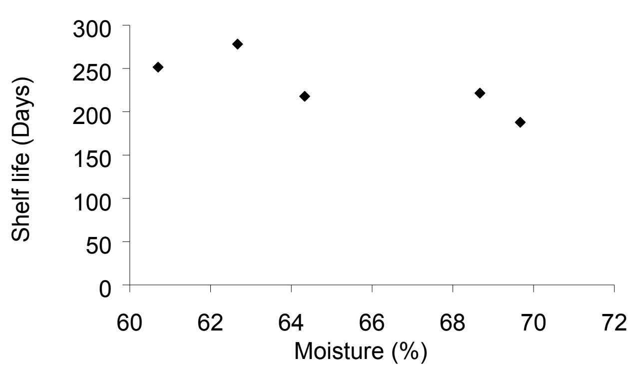

Fig. 3. Correlation between Shelf life and Moisture content (*r* = -0.80538)

There was no significant correlation between percentage content of protein and shelf life of the yams (*r* = -0.44955). However, var. abana mmee with the highest percentage content of protein had the shortest shelf life, while var. abi with very low percentage protein content demonstrated the longest shelf life of the yams studied. While higher concentration of proteins in yams may confer an advantage from the nutritional view point, they may compromise shelf life. Kumar et al. [18] have reported that proteins undergo breakdown during the storage of potatoes. Higher concentrations of protein or their breakdown components will support higher rates of microbial spoilage as observed during this study. Additionally, high concentrations of proteins may suggest higher concentrations of endogenous enzymes, including oxidizing enzymes and therefore higher rates of tissue degradation during the storage of yams. The Nitrogen content of the yams is directly related to protein content (r = -0.42454).

Lipolysis and oxidation of lipids in foods are the major biochemical and chemical processes that cause food quality deterioration, leading to the characteristic, unpalatable odour and flavour called rancidity. In this study however, percentage fat content in the tubers was observed to correlate positively and significantly (P = 0.05) with shelf life of the yams (Fig. 4). It is noteworthy that lipolysis and oxidation are dependent on the extent of hydrogenation of the fats present in a food. Presence of hydrogenated fats (transfats) is in fact known to extend the shelf life of foods (Wikipedia.org, 2013). This may be associated with their low susceptibility to both chemical reactions and microbial breakdown. Furthermore, the concentrations of fat in these yams are relatively small compared with concentrations in foods susceptible to rancidity. Small concentrations of fat present in yams may therefore serve the purpose of stabilization of the other tuber components.

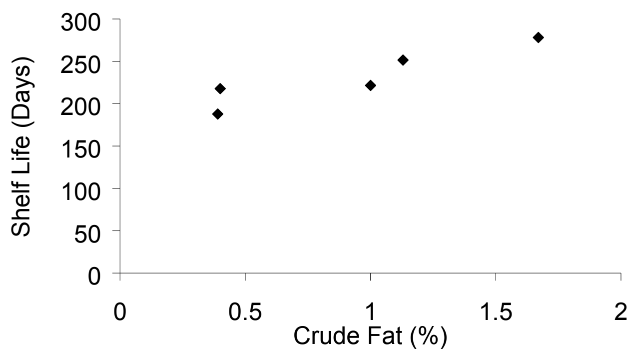

Fig. 4. Correlation between Shelf life and Fat content (*r*= 0.921058)

Carbohydrates are the major components consumed by physiological changes during the storage of the yam tuber. Thus, during the storage of yams, there is a decrease in starch content and an increase in the total alcohol-soluble sugars and reducing sugars [15]. Correlation between carbohydrate content and shelf life was insignificant but positive (r = 0.790891). A greater reservoir of this component ensures a longer sustenance of the life of the tuber. There was also a poor correlation (r = 0.357047) between fibre content and shelf life. During the storage of yams, while the fibre content increases, there is a reduction in mineral content [15].

The role of the chemical composition of yams in their shelf lives will no doubt, derive from a composite influence of all substances present and their concentrations. For instance, the relatively long shelf life observed in var. abi may have been derived from its relatively low moisture and protein content, its relatively high fat and carbohydrate content and additionally, the presence of antimicrobial substances in its peel. This combination of components may have also ensured its low susceptibility to microbial attack. The poor keeping of var. abana mmee and its high susceptibility to microbial attack could be attributed to its near opposite chemical composition.

5. CONCLUSION

This work has revealed the general similarity in proximate composition between yams cultivated in Eastern Nigeria and yams reported in literature from other parts of the world. Significant varietal differences are also common among these yams as well. During storage, physiological changes such as moisture loss may occur to different extents in different yams. Hence different varieties of yams maintain different levels of moisture (%) during their storage. Respiration, on the other hand appears to share the same characteristics in all the yam varieties studied. The chemical composition of yams plays a role in the determination of their shelf lives. High moisture content in tubers at harvest and during storage tends to predispose them to a short shelf life, while high concentration of fats and carbohydrates guarantee longer shelf lives. Some varieties of *D. rotundata* (var. abi) can keep for up to 40 weeks. Research efforts aimed at the improvement of other desirable characteristics such as yield in this variety will help reduce post harvest losses during storage and hence improve yam production.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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