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PROXIMATE COMPOSITION OF REGIONS OF *Dioscorea bulbifera* (L.) and *Dioscorea rotundata* (L.) TUBER DURING STORAGE

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Abstract

There has been so much speculations about the nutritional quality of yams at different stages of storage. Sometimes tubers at post sprouting stages are crudely rejected for food without scientific evidence. This study was therefore designed to ascertain the proximate composition of two species of yam; *Dioscorea bulbifera* L. and *Dioscorea rotundata* L. during storage. The objectives of the study included to ascertain the composition of the proximate in white and aerial yams. There was also the objective of finding out the value and mobilization of the nutrients within the three regions of both yam species. Yams used for the study were harvested the same day under special arrangement with a farmer. The tubers selected were closely of the same size, healthy looking and unbruised. Each tuber for analysis was divided into three regions as the head, the middle and the tail parts. The tubers were analyzed at three stages of storage as: initial stage (immediately after harvest); pre-sprouting stage (midway through storage before sprouting), and post-sprouting stage (after sprouting). Proximate assay was carried out using standard methods. At each stage of storage, three tubers of each species were used for

Key words:
Dioscorea, proximate, storage, sprouting, mobilization

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each assay and the analysis was replicated three times. A completely randomized design was used for the experiments. Results showed that at harvest the moisture content was highest at the tail region (66.19% and 64.83% respectively for white yam and aerial yam). At harvest, the carbohydrate composition of both white yam and aerial yam were highest (82.96% and 78.91% respectively) at the tail region. At post-sprouting stage, protein content of the head region of aerial yam was significantly highest as 7.44%. In all, the nutritional value of yam during storage is species dependent. White yam remains satisfactorily nutritious even at post-sprouting stage and the head region proved to be the most valued part. In the aerial yam, the nutritional value reduced substantially at post-sprouting although the differences were not significant.

Introduction

Small scale and mechanized farmers cultivate the tuber crop yam (*Dioscorea* spp.) throughout the tropics (Andres *et al*., 2017; Frossard *et al*., 2017). *Dioscorea alata* (water yam), *D. bulbifera* (aerial yam), *D. dumentorum* (trifoliate yam) and *D. rotundata* (white yam) are the species that are most significant (Arnau *et al.,* 2010). In addition to being a basic food consumed by 155 million people, yams are also grown for money and as a medicine, and some of the groups that grow them place a high importance on their culture (Sangakkara and Frossard, 2014; Frossard *et al*., 2017). Despite being significant, yam is still an orphan crop (Kennedy, 2003; Naylor *et al*., 2004; Frossard *et al*., 2017).

Yam provides immense promise for developing nations' economies, industry, healthcare, and general food security (Obidiegwu *et al.*, 2020). Yams rank second in West Africa behind cassava and are the fourth most widely grown root and tuber crop globally, behind potatoes (*Solanum* spp.), cassava (*Manihot esculenta Crantz*), and sweet potatoes (*Ipomoea* spp.). Yam's potential as a source of food is attributed to its high quantities of carbohydrates, including fiber, starch, and sugar, which provide more than 300 million people in the tropics with roughly 200 dietary calories per person per

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day. Also, it offers other nutritional advantages such as proteins, lipids, vitamins, and minerals (Nweke *et al*. 2013; Padhan and Panda, 2020).

The quest for a food secure and safe world has led to continuous effort toward improvements of global food and health systems. While the developed countries seem to have these systems stabilized, some parts of the world still face enormous challenges especially in Sub-Saharan Africa. Studies to improve the nutritional (food) and non-nutritional (health) benefits of yam as a food crop has been given little or no attention. However, consumers of this food crop 'yam' see the crop as sole supply of carbohydrates to their diet with no knowledge that it contains protein, lipids, vitamins, minerals and other essential elements needed for proper growth and development. More so, previous research on the mobilization of seed reserves during germination has mainly concentrated on one specific reserve type (Kim *et al*., 2009; Shaik *et al.*, 2014) or a single species of a crop (Goyoaga *et al.*, 2011; Atade *et al.*, 2013; Lopes *et al*., 2013), with little focus on *Dioscorea* spp. in Nigeria.

This study was designed to evaluate the proximate composition of the regions of tuber of *Dioscorea bulbifera (*L.) and *Dioscorea rotundata (*L.) during storage. The specific objectives were to ascertain the effect of sprouting on the concentration of proximates in *Dioscorea bulbifera* and *D. rotundata* and to determine the concentration of these nutrients in each tuber region/section at different storage times across the two yam species.

MATERIALS AND METHODS

Source of materials

The tubers of *Dioscorea bulbifera* and *D. rotundata* used in the study were harvested from a farm at Umudike Umuahia Abia State Nigeria under special arrangements with a farmer. Immediately after harvest, these tubers were taken to the laboratory for storage in the laboratory's storage section. The yams were stored in an open, ventilated yam barn as the usual storage space for yam.

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Experimental Design

This experiment was arranged in a Completely Randomized Design (CRD) as the experimental units were completely replicated at random. Data collected were subjected to Analysis of Variance (ANOVA) and test of significance was carried out using Duncan's multiple Range test (Duncan, 1955) to separate the means.

Experimental Procedure

Analysis of tubers of the two species of yam during storage were carried out at three (3) stages of storage (storage times) viz: immediately after harvest, midway through storage before sprouting (pre-sprouting) and after sprouting (post-sprouting) stages. The pre-sprouting stage was 6-7 weeks after harvest while post-sprouting stage was one (1) week into sprouting. At every stage, three (3) tubers of each species were randomly selected and each of the tubers was cut into head, middle and tail regions (sections). Analysis was carried out for proximate composition. Tubers used for this experiment were peeled after separation into head, middle and tail regions and the respective peel-free tubers were dried to constant weight at 70°C. The dried samples were ground to flour (using analytical mill A-10), sieved through a 1mm mesh size sieve and preserved in air tight packs made of polythene prior to analysis.

Proximate Analysis

The proximate investigations were done with the methods of Onwuka (2018) in the determination of moisture content, crude protein content, fat content, crude fibre, ash and carbohydrate.

Determination of moisture content

The metal dishes were washed and thoroughly dried in an oven. They were put into a desiccator to cool and was weighed (W_1). Two grammes of the samples were weighed and put into the weighed dish (W_2). The average weight was taken after drying and weighing. The samples were dried at 105°C for 4 hours

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until a constant weight was obtained. They were allowed to cool and the weight of the dry samples and dishes were taken and this was labeled W_3.

The percentage moisture content was calculated as

$$\%\text{moisture} = \frac{W_2 - W_3}{W_2 - W_1} \times \frac{100}{1}$$moisture=W_2-W_3/W_2-W_1×100/1moisture=W_2-W_3/W_2-W_1×100/1

Where;

$W_1 = \text{Initial weight of the empty dish}$

$W_2 = \text{Weight of the dish} + \text{undried sample}$

$W_3 = \text{Weight of dish} + \text{dried sample}$

Determination of crude protein content

Two grams (W) of each of the samples were mixed with 10 ml of concentrated H_2SO_4 in a heating tube. One tablet of selenium catalyst was added to the tube and the mixture was heated inside a fume cupboard. The digest (vf) was transferred into a 100 ml volumetric flask and made up with distilled water. A 10 ml portion of the digest was mixed with equal volume of 45% of NaOH solution and poured into a kjeldahl distillation apparatus. The mixture was distilled as the distillate was collected into 4% boric acid solution containing 3 drops of screened methyl red indicator. A total of 50 ml distillate (Va) was collected and titrated against 0.02 N H_2SO_4 solution (N) to obtain a titre value (T).

A reagent blank was also distilled and titrated as well. The samples were each duplicated and the average value was taken. The nitrogen content was calculated and multiplied with 6.25 to obtain the crude protein content.

The calculation is shown below:

$$\%\text{Nitrogen} = \left(\frac{100}{W} \times \frac{N \times 14}{100} \times \frac{Vf}{Va}\right) T$$Nitrogen=100/W×N×14/100×Vf/VaTNitrogen=100/W×N×14/100×Vf/VaT

Nitrogen=100/W×N×14/100×Vf/VaT

Where;

$W = \text{ weight of the sample}$

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N = normality of the titrant (0.02 N)

Vf = Total volume of the digest = 100 ml; T = Titre value

Determination of fat content

A 200 ml clean boiling flask was dried in an oven at 105 °C for about 30 min. The flask was transferred into a desiccator and allowed to cool and it was labeled W_1. Five (5) grams of the sample (W_3) was weighed into well labeled thimbles. The samples were wrapped with filter paper and put into a soxhlet flask containing 200 ml of petroleum ether. The upper end of reflux flask was allowed to reflux for about 4 hours as the sample was applied through electro thermal heater. The heated solvent vaporized and condensed into the reflux flask containing the sample. The wrapped sample was completely immersed in the solvent and remained in the contact with it until the flask filled up and siphoned over thus carrying extracted oil from the samples down to the boiling flask.

The oil extracted into the flask was removed from the set up and dried for 3min (to remove any residual solvent) and transferred to the desiccator and weighed (W_2). The percentage fat content was calculated:

$$\% \text{ fat content} = \frac{W_2 - W_1}{W_3} \times \frac{100}{1}$$

Where, W_1= weight of the empty extraction flask

W_2= weight of the flask and oil extraction

W_3= weight of the sample

Determination of crude fiber

Two (2) grams of each sample (W_1) was defatted and transferred into a 250 ml conical flask. The samples were boiled under flux for 30 min with 200 ml 1.25 % H_2SO_4. The sample was filtered through muslin cloth and washed with boiled water and transferred back into the 250 ml conical flask, after which it was allowed to boil for 30 min with 200 ml of 1.25 % of NaOH. The final residue was filtered through a muslin cloth. The final residue was transferred into a clean

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crucible and dried in an oven for one hour, cooled and weighed (W_2). The loss in weight (W3) after incineration in a muffle furnace at 550°C x 100 is the percentage of the crude fiber.

The crude fibre content was calculated as:

$$\% \text{ Crude Fibre} = \frac{\text{Loss in weight after incineration}}{\text{Weight of sample}} X\frac{100}{1}100/1100/1 = \frac{W_2 - W_3}{\text{Weight of sample}}$$

W_2 = Weight of crucible sample after washing and drying in oven

W_3 = Weight of crucible + sample ash

Determination of ash

Empty crucibles were dried in a hot air oven and cooled (W_1). The measured weight (2 g) of each sample was put into the weighed crucibles (W_2). The sample in crucible were put in a muffle furnace set at 550 °C and allowed to burn for 2-3 h (until the sample became grey ash). The sample in crucible was carefully removed from furnace and cooled in a desiccator and reweighed (W_3). The weight of the ash was obtained and expressed as a percentage given by the formula:

$$\% \text{ Ash} = \frac{W2-w3}{w2-w1} x \frac{100}{1}$$

Where,

W_1= weight of empty crucible

$W_{2=}$ weight of crucible + sample

W_3= weight of crucible and sample after ashing.

Determination of Carbohydrate

The carbohydrate content was calculated by difference described by free extraction (NFE). The NFE was obtained by % NFE= 100-% (a+b+c+d+e)

a= protein

b= fat

c= crude fiber

d= ash content

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e= moisture

RESULTS

1. Percentage proximate composition of different sections of aerial yam tuber during storage

Results of the moisture content of aerial yam showed that at harvest, the tail region gave significantly highest level (64.83%) while the head region gave the lowest moisture content (56.85%). At pre-sprouted stage, the head region retained the lowest (49.07%) and the sequence as tail, middle and head continued during the post-sprouted stage. **(Table 1)**

Results of the protein contents of aerial yam showed that at harvest, the head region gave significantly highest level (7.08%), the tail giving the least (6.90%). At pre-sprouted stage, the middle region showed the highest protein content (7.15%) while the head region gave the least (7.07%). At the post-sprouted stage, the highest protein composition was observed at the head region (7.44%) while the middle region gave the least (7.21%). **(Table 1)**

Results of fat content of aerial yam showed that at harvest, the tail region gave significantly highest level (0.63%) while the head region gave the lowest (0.49%). The sequence as tail, middle and head continued during the pre-sprouted and post-sprouted stages. **(Table 1)**

The Carbohydrate contents of aerial yam showed that at harvest, the tail region gave significantly highest level (78.91%) slightly higher than the middle (78.81%) and the head region (78.65%). This sequence as tail, middle and head continued at both the pre-sprouting and post-sprouting stages. **(Table 1).**

Table 1: Percentage proximate composition [b] of different sections of aerial yam tuber during storage

Tuber Region	MOISTURE CONTENT	CRUDE PROTEIN	FAT	CRUDE FIBRE	ASH	CHO
AT HARVEST						
HEAD I	$56.85^{c} \pm 0.46$	$7.08^{bc} \pm 0.13$	$0.49^{d} \pm 0.020$	1.53 ± 0.07^{ab}	2.97 ± 0.01^{cd}	78.65 ± 0.15^{a}
MID I	$61.53^{b} \pm 0.43$	$6.91^{c} \pm 0.22$	$0.57^{c} \pm 0.01$	1.23 ± 0.01^{b}	3.22 ± 0.07^{c}	78.81 ± 0.21^{a}
TAIL I	$64.83^{a} \pm 2.00$	$6.90^{c} \pm 0.007$	$0.63^{a} \pm 0.02$	$1.09 \pm 0.02bc$	$3.23 \pm 0.01c$	78.91 ± 0.11^{a}

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PRE-SPROUTING							
HEAD 2	$49.07^{g} \pm 0.82$	$7.07^{bc} \pm 0.22$	$0.45^{e} \pm 0.01$	1.64 ± 0.02^{a}	3.47 ± 0.03^{bc}		78.10 ± 0.25^{b}
MID 2	$53.21^{e} \pm 0.36$	$7.15^{b} \pm 0.002$	$0.52^{d} \pm 0.02$	1.29 ± 0.02^{b}	3.71 ± 0.10^{ab}		$78.09 \pm 0.11_{b}$
TAIL 2	$57.36^{c} \pm 0.83$	$7.11^{bc} \pm 0.02$	$0.61^{ab} \pm 0.02$	1.15 ± 0.01^{bc}	3.47 ± 0.09^{bc}		78.64 ± 0.33^{ab}
POST-SPROUTING							
HEAD 3	$46.39^{h} \pm 0.47$	$7.44^{a} \pm 0.07$	$0.44^{e} \pm 0.01$	1.17 ± 0.03^{bc}	3.87 ± 0.05^{ab}		77.30 ± 0.09^{bc}
MID 3	$51.68^{f} \pm 0.34$	$7.21^{ab} \pm 0.02$	$0.49^{d} \pm 0.01$	1.33 ± 0.01^{b}	4.42 ± 0.47^{a}		77.57 ± 0.15^{bc}
TAIL 3	$54.21^{d} \pm 0.39$	$7.22^{b} \pm 0.05$	$0.59^{bc} \pm 0.02$	1.17 ± 0.02^{bc}	3.51 ± 0.03^{bc}		78.24 ± 0.13^{b}

Values are means of triplicate analysis ± standard deviation.

Figures with different superscripts in the column are significantly different ($P<0.05$).

CHO ≡CARBOHYDRATE

Percentage proximate composition of different sections of white yam tuber during storage

Results of the moisture content of white yam showed that at harvest, the tail region gave significantly highest level (66.19%) while the middle region gave the lowest moisture content (62.93%). At pre-sprouted stage, the tail region gave the highest moisture content (57.31%) while the head region gave the lowest (54.84%). The head region retained the lowest moisture content (50.39%) at the post-sprouted stage with a slight increase at the middle and tail. **(Table 2)**

Results of the protein contents of white yam showed that at harvest, the head region gave significantly highest level (2.91%) while the tail region gave the lowest protein content (2.69%). At pre-sprouted stage, the tail region retained the lowest protein content (2.91%). This sequence as head, middle and tail continued at the post-sprouted stage. **(Table 2)**

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Results of the fat contents of white yam showed that at harvest, the tail region gave significantly highest level (0.49%) while the head region gave the lowest fat content (0.43%). At post-sprouted stage, the head region retained the lowest fat content (0.45%). **(Table 2)**

The Carbohydrate contents of white yam showed that at harvest, the tail region gave significantly the highest (82.96%) slightly higher than the middle (82.89%) and the head region (82.67%). This sequence as tail, middle and head continued at both the pre-sprouting and post-sprouting stages. **(Table 2)**

Results of the fibre contents of white yam showed that at harvest, the head region gave significantly highest level (2.07%) while the tail region gave the lowest fibre content (1.95%). At pre-sprouted stage, the head region gave the highest fibre content (2.26%) while the tail region gave the lowest (2.11%). Same sequence in post-sprouted stage. **(Table 2)**

Table 2: Percentage proximate composition of different sections of white yam tuber during storage

Tuber Region	Moisture Content	FAT	CRUDE FIBRE	ASH	CRUDE PROTEIN	CHO
AT HARVEST						
HEAD I	$64.24^{c} \pm 0.25$	$0.43^{abc} \pm 0.03$	$2.07^{ef} \pm 0.08$	$2.85^{b} \pm 0.08$	$2.91^{abc} \pm 0.08$	$82.67^{a} \pm 0.09$
MID I	$62.93^{b} \pm 0.36$	$0.45^{bc} \pm 0.01$	$2.01^{b} \pm 0.01$	$2.87^{b} \pm 0.01$	$2.76^{cd} \pm 0.11$	$82.89^{a} \pm 0.22$
TAIL I	$66.19^{a} \pm 0.29$	$0.49^{ab} \pm 0.01$	$1.95^{a} \pm 0.01$	$2.86^{b} \pm 0.01$	$2.69^{d} \pm 0.11$	$82.96^{a} \pm 0.10$
PRE-SPROUTING						
HEAD 2	$54.84^{c} \pm 0.25$	$0.51^{a} \pm 0.02$	$2.26^{abc} \pm 0.01$	$3.02^{ab} \pm 0.04$	$3.04^{ab} \pm 0.11$	$82.29^{b} \pm 0.10$
MID 2	$56.31^{d} \pm 0.14$	$0.50^{a} \pm 0.02$	$2.13^{de} \pm 0.01$	$3.33^{a} \pm 0.62$	$3.02^{ab} \pm 0.011$	$82.60^{ab} \pm 0.36$

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TAIL 2	$57.31^{d} \pm 0.14$	$0.49^{ab} \pm 0.02$	$2.11^{a} \pm 0.02$	$2.93^{ab} \pm 0.04$	$2.91^{abc} \pm 0.08$	$82.63^{ab} \pm 0.19$
POST-SPROUTING						
HEAD 3	$50.39^{g} \pm 0.84$	$0.45^{bc} \pm 0.01$	$2.21^{cde} \pm 0.01s$	$2.93^{ab} \pm 0.07$	$3.07^{a} \pm 0.18$	$82.62^{ab} \pm 0.00$
MID 3	$51.35^{f} \pm 0.38$	$0.48^{c} \pm 0.01$	$2.19^{bcd} \pm 0.02$	$2.95^{ab} \pm 0.01$	$2.91^{abc} \pm 0.08$	$82.70^{a} \pm 0.09$
TAIL 3	$51.19^{f} \pm 0.48$	$0.45^{bc} \pm 0.01$	$2.18^{b} \pm 0.05$	$2.62^{b} \pm 0.05$	$2.87^{bc} \pm 0.08$	$82.71^{a} \pm 0.06$

Values are means of triplicate analysis ± standard deviation.
Figures with different superscripts in the column are significantly different (P<0.05).

DISCUSSION

Results of the moisture content showed that in aerial yam, the tail region gave the highest moisture content (64.83%) at harvest but decreased significantly at the post-sprouting stage (54.21%). The head region which showed the lowest moisture content 56.85% at harvest also reduced to 46.39% after sprouting (Table 1). The moisture content of the white yam also followed similar pattern of being higher in the tail region at harvest (66.19%) and lower in the head region at harvest (64.24%) (Table 2). These showed that during storage of yam, proximate composition of its moisture content tend to increase more towards the tail than towards the head. These results are in line with that of some workers. Similar results were reported by Kadiri "et al." (2014) and Dutta. (2015) who stated that yam practically had more of moisture content at the tail during storage. Practically, factors such as cultivar or species involved, nature of the soil and the season in which the yam was planted may have led to this outcome. More so, sprouting had a significant effect on moisture content of yam; this means that as the yam stays in storage and ages towards sprouting which

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preferably occurs at the head region, utilization of water increases leading to less availability of water at the head region.

Results of the protein content of aerial and white yam tubers showed that the head region gave the highest protein content (7.44%) and (3.07%) respectively after sprouting taking a leap from 7.08% and 2.91% respectively, they had at harvest. It is worthy to note that midway through storage, noticeable increases were observed at the middle region (7.15%) and (3.02%) respectively. The tail region of aerial and white yams recorded the lowest protein content (6.9%) and (2.69%) respectively at harvest (Table 1 and 2 respectively). The high protein content of the head region agrees with the study carried out by Leonel "et al." (2017) and Obidiegwu "et al." (2020) who stated separately that protein composition of aerial yam increased towards the head of aerial yam during storage. This may be explained from the fact that higher protein content indicates an increased number of free amino acids which may have been released during germination. Sprouting also had a significant increasing effect on protein content of yam.

From the data gathered, the fat content of aerial and white yam tubers showed that the tail region gave the highest fat content (0.63%) and (0.49%) respectively at harvest while the head region gave the lowest fat content (0.44%) and (0.45%) respectively after sprouting. The higher fat content in the tail region of yam agrees with the study of Asha and Nair (2005); Nayaboga "et al." (2014) and Mulualem "et al." (2018). The result of their studies revealed that during the storage of yam, fat increased at the tail and decreased in the head.

The finding that in aerial and white yam tubers, the head region gave the highest fibre content (1.64%) and (2.26%) respectively before sprouting while the tail region gave the lowest fibre content (1.09%) and (1.95%) respectively at harvest (Table 1 and 2 respectively) is similar to the study carried out by Jayakody "et al." (2007) and Asha and Nair (2005); who stated separately that during the storage of yam fibre increased at the head and decreased during the sprouting time.

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Results showed that the ash content of aerial yam was more in the middle (4.42%) during the post-sprouting period and lowest in the head region (2.97%) at harvest (Table 1). This may be an indication that sprouting had a significant effect on ash content of aerial yam. Contrastingly, the ash content of white yam was more in the middle (3.33%) before sprouting and lowest in the head region (2.85%) at harvest (Table 2). The higher ash content of the middle part of yam tuber agrees with the work of Wireko-Manu "et al." (2013) and Van Eck (2007), who reported separately that during the storage of yam, ash increased at the middle and decreased in the head.

Results of the proximate composition of aerial yam tuber showed that Carbohydrates were mostly concentrated at the tail region (78.91%) at harvest while the lowest concentration of Carbohydrates was seen at the head region (77.3%) after sprouting. The carbohydrate composition of the white yam also followed similar pattern of being higher in the tail region at harvest (82.96%) but was lower at the head region (82.29%) before sprouting. This is in line with the reports of the study carried out by Otegbayo "et al." (2014) and Obidiegwu "et al." (2020) who reported separately that during the storage of yam carbohydrates increase at the tail and decrease in the head.

CONCLUSION

In all, the nutritional value of yam during storage is species dependent. White yam remained satisfactorily nutritious even at post sprouting stage. Interestingly however, the head region proved to be the most valued part. In the aerial yam, the nutritional value reduced substantially at post-sprouting although the differences were not significant. Consumers are however advised to make best use of these tuber species at every stage during storage since they still retain substantial amounts of nutrients at each stage.

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