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Effect of temperature treatment on the chemical composition, microbiology and sensory evaluation of Yam chips during storage

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Abstract
Dioscorea rotundata cv. I-212 which have high dry matter and low sugar content harvested from All India Coordinated Research Project on Tuber Crops, BCKV, West Bengal, was used for making chips following dehydration at different temperatures (40, 50 and 60) °C for 12±2 hours. Monthly evaluation of the changes in proximate nutritional composition; anti-nutritional composition; microbial count and sensory evaluation of the Yam Chips during storage at room temperature were carried out using standard methods. A significant difference ($p<0.05$) existed between the means of the proximate compositions among the yam chips except for fat, beta-carotene and calcium oxalate. Yam chips dehydrated at 50 °C, (12±2) hrs. were found to retain high nutrient and low antinutrient values with desirable sensory attributes and minimal microbial counts for 3 months. Therefore, yam chips can be safely stored and used as reliable and energy security food if dehydrated at the specified temperature and duration.

Keywords: yam; composition; microbial count; sensory; storage

1. Introduction
Yam tubers are composed of a high moisture content (55-75%) and dry matter. The dry matter is predominantly composed of carbohydrates (65-80%), vitamins (ascorbic acid, β-carotene and riboflavin), protein (1-2%, fresh weight), in addition to sugars and minerals (iron, calcium, phosphorous and ash) as reported by Eka, 1983 [9]; Olayiwola and Okhiria, 2012 [23]. This high dry matter and carbohydrate content of yam fulfil the important criteria for making chips. Yam chips can be completely dried using the energy from the sun and the wind. However, the drying period is mostly much longer and frequently takes between two and three weeks (Mestres *et al*., 2004) [19]. During the long drying, period the chips often become mouldy and ferment. This makes the chips discoloured and also changes their flavour. Chips laid out to dry are often spoiled by rain, sand and animal excrement which leads to losses in quality due to hygiene (Adams and Moss, 1991) [1]. The yam chips are hygroscopic and tend to draw moisture which promotes the formation of mould and thus early deterioration (Frazier and Westhoff, 2003) [12]. The condition of the product is influenced by the environment during growth and maturation, the degree of microbial invasion, the maturity at harvest, the methods of handling prior to and after crack and mechanical damage or breakage and predispose stored products to microbial invasion. Therefore, considering the above facts the objective of this paper is to investigate the cabinet dried yam chips for its proximate composition, microbiology and sensory and also its effect during storage at room temperature.

2. Materials and Methods
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Fresh Yam tuber of *D. rotundata* cv. I-212 harvested 9month after planting (full mature stage) were collected from All India Coordinated Research Project on Tuber Crops, grown in the research field at Mondouri, Bidhan Chandra Krishi Viswavidyalaya, Nadia, West Bengal, India. Quantitative analysis was done in the laboratory of Department of Postharvest Technology, Bidhan Chandra Krishi Viswavidyalaya, Nadia, West Bengal, India. Fresh undamaged yam tubers were peeled, cut into small slices (2-3mm) and then blanched by dipping at the water (90^0C) for 5 mins. After blanching, cabinet drying of the sample was done at different temperature 40 °C (T1), 50 °C (T2) and 60 °C (T3) for 10-14 hours. The dehydrated product was then packed in polyethylene and stored at room temperature. Analysis of biochemical, microbial and sensory characteristics was carried out at 30 days' intervals for 4months.

2.1 Proximate analysis of nutrient and antinutrient

Moisture content was determined using AOAC (2005) [6] method. Spectrophotometrically (UV/VIS Spectrophotometer, Model-Optizen POP, Korea) determination (Sadasivam and Manickam, 2011) [29] method for carbohydrate, starch and total soluble sugar using anthrone reagent at wavelength 630nm, protein content using Folin-Ciocalteau reagent at wavelength 660nm, β-carotene content at wavelength 452nm, total phenol content using Folin-Ciocalteau reagent at wavelength 650nm and tannin content using Folin-Denis reagent at wavelength 700nm.The antioxidant activity i.e. scavenging of DPPH (1,1-diphenyl-2-picrylhydrazyl) radical was carried out according to the method described by Hsu *et al*. (2003) [14]. Estimation of fat is done by using organic solvents and quantification by gravimetry method (Folch *et al*., 1957) [11]. Ascorbic acid was determined by the titration method using 2, 6 dichlorophenol indophenol solution as described by Sadasivam and Manickam (2011) [29]. Trypsin inhibitor (Sumathi and Pattabiraman, 1995) [32] using casein reagent at wavelength 660nm. The subsequent analysis for oxalate content was made following the methods of AOAC (2005) [6]. Holloway *et al.* (1989) [13] reported that the water extraction gave soluble oxalates, and extraction with acid gave total oxalates. The difference between them equated the amount of calcium oxalate. Microbial count by dilution plate method i.e. Nutrient yeast agar media to detect bacteria (Lapage *et al.,* 1970) [16] and Rose Bengal Agar a selective medium to detect and enumerate yeasts and moulds in food samples (Beuchat and Cousin, 2001) [8]. Sensory evaluation of the samples for colour and texture was determined by 5point hedonic scale (Ranganna, 2000) [28].

2.2 Statistical analysis

Duncan test was done on IBM SPSS STATISTICS 19 software to determine the significant difference between treatments.

3. Results and Discussion

3.1 Proximate composition

Table no.1 showed the proximate composition of the prepared yam chips and were described as follows.

Table 1: Nutrients and antinutrients evaluation of dehydrated Yam chips

Parameter	Raw Sample	Dehydrated Sample	Storage Duration (In Month)				
			0	1	2	3	4
Moisture (%)	63.9	T1	9.4^{a}	9.6^{a}	9.9^{a}	10.1^{a}	10.2^{a}
		T2	9.1^{b}	9.2^{b}	9.5^{b}	9.6^{b}	9.7^{b}
		T3	8.8^{c}	9.1^{b}	9.2^{c}	9.4^{b}	9.6^{b}
Carbohydrate (%)	82.3	T1	85.6^{b}	84.3^{b}	81.3^{b}	79.1^{c}	77.3^{c}
		T2	86.1^{ab}	85.1^{ab}	83.1^{a}	81.3^{b}	79.4^{b}
		T3	86.6^{a}	85.4^{a}	84.5^{a}	82.3^{a}	80.6^{a}
Starch (%)	27.5	T1	37.5^{c}	34.2^{c}	30.6^{c}	28.2^{c}	24.7^{c}
		T2	38.4^{b}	36.2^{b}	32.1^{b}	29.8^{b}	26.6^{b}
		T3	39.1^{a}	36.8^{a}	32.6^{a}	30.5^{a}	27.5^{a}
Total Sugar (%)	2.5	T1	3.1^{c}	2.7^{c}	2.5^{c}	2.1^{c}	1.7^{c}
		T2	3.4^{b}	3.2^{b}	2.8^{b}	2.4^{b}	1.9^{b}
		T3	3.7^{a}	3.5^{a}	3.1^{a}	2.7^{a}	2.2^{a}
Protein (%)	1.3	T1	1.23^{a}	1.18^{a}	1.14^{a}	1.11^{a}	1.03^{a}
		T2	1.19^{b}	1.15^{b}	1.12^{a}	1.08^{b}	0.97^{b}
		T3	1.17^{b}	1.14^{c}	1.09^{b}	1.01^{c}	0.91^{c}
Fat (%)	0.22	T1	0.17^{a}	0.16^{a}	0.13^{a}	0.12^{a}	0.11^{a}
		T2	0.16	0.14	0.12	0.11	0.09
		T3	0.14	0.13	0.11	0.10	0.08
Vitamin C (Mg/100g)	7.4	T1	5.7^{a}	4.8^{a}	4.2^{a}	3.9^{a}	2.8^{a}
		T2	4.9^{b}	4.3^{b}	3.6^{b}	3.2^{b}	2.5^{b}
		T3	4.4^{c}	3.8^{c}	3.2^{c}	2.8^{c}	2.1^{c}
B-Carotene (Mg/100g)	0.32	T1	0.19^{a}	0.17^{a}	0.15^{a}	0.13^{a}	0.09^{a}
		T2	0.18	0.16	0.14	0.12	0.07
		T3	0.16	0.15	0.12	0.11	0.05
Antioxidant (%)	78.9	T1	19.4^{a}	17.5^{a}	12.5^{a}	9.4^{a}	7.5^{a}
		T2	18.6^{b}	16.7^{b}	10.6^{b}	8.5^{b}	6.4^{b}
		T3	15.5^{c}	14.8^{c}	9.4^{c}	5.5^{c}	4.7^{c}
Phenol (Mg/100g)	53.2	T1	24.3^{a}	21.5^{a}	19.4^{a}	17.2^{a}	15.3^{a}
		T2	22.4^{b}	20.6^{b}	18.8^{b}	16.5^{b}	14.2^{b}
		T3	20.2^{c}	18.6^{c}	15.2^{c}	12.7^{c}	12.2^{c}
Tannin (Mg/100g)	4.2	T1	2.6^{a}	2.3^{a}	2.1^{a}	1.9^{a}	1.7^{a}
		T2	2.5^{a}	2.1^{a}	1.8^{b}	1.7^{b}	1.6^{a}
		T3	2.2^{b}	1.9^{b}	1.7^{b}	1.6^{b}	1.4^{b}
Trypsin Inhibitor (Mg/G)	1.1	T1	0.22^{a}	0.19^{a}	0.18^{a}	0.16^{a}	0.15^{a}
		T2	0.18^{b}	0.17^{b}	0.14^{b}	0.13^{b}	0.12^{b}
		T3	0.16^{c}	0.15^{c}	0.13^{b}	0.12^{c}	0.11^{b}
Total Oxalate (Mg/100g)	0.53	T1	0.25^{a}	0.22^{a}	0.20^{a}	0.19^{a}	0.16^{a}
		T2	0.23^{b}	0.21^{ab}	0.18^{ab}	0.17^{b}	0.14^{ab}
		T3	0.22^{b}	0.19^{b}	0.17^{b}	0.15^{c}	0.13^{b}
Water Soluble Oxalate (Mg/100g)	0.38	T1	0.14^{a}	0.13^{a}	0.11^{a}	0.10^{a}	0.08^{a}
		T2	0.13^{b}	0.12^{a}	0.09^{b}	0.08^{b}	0.07
		T3	0.11^{c}	0.09^{b}	0.08^{b}	0.06^{b}	0.05

Calcium Oxalate (Mg/100g)	0.15	T1	0.11[a]	0.09[a]	0.09[a]	0.09[a]	0.08[a]
		T2	0.10	0.09	0.09	0.09	0.07
		T3	0.11	0.08	0.07	0.07	0.06

Note:
Where, Dehydration temperature for T1= 40 ^{0}C; T2= 50 ^{0}C and T3= 60 ^{0}C
The values are means.
Values in the same column followed by different superscripts are significantly different ($p<0.05$).
[A] Values in the same column are not significantly different.

3.1.1 Moisture
The moisture content varies significant with different dehydrated temperature, were higher dehydrated temperature have low moisture content compared to lower dehydrated temperature. Moisture content was low in T3 (8.8%), high in T1 (9.4%) and moderate in T2 (9.1%) which agrees with the moisture content of processed yam chips as reported by Ojokoh and Gabriel (2010) [22]. During storage moisture content tends to increase in all the samples. The value of T1, T2 and T3 ranges from 9.4 -10.2%; 9.1-9.7% and 8.8-9.6% respectively, during the storage period. These increased in moisture content during storage corroborates the findings of Babajide and Oyebanjo (2010) [7] and Adegunwa *et al*. (2011) [2]. The increase in moisture might be caused by absorption from the environment and aerobic respiration of the microorganisms which normally leads to the release of water and carbon dioxide (Muir, 1994).

3.1.2 Carbohydrate
The result presented in Table no.1 showed that, carbohydrate content (%) of the samples. It is observed that carbohydrate content in yam chips increases with increase in dehydration temperature were T3 (60 ^{0}C) treatment contain the highest (86.6%) followed by T2 (50 ^{0}C) with value 86.1% and T1 (40 ^{0}C) the lowest (85.6%). It is clearly observed that during storage the carbohydrate content decreases linearly. The value of T1, T2 and T3 ranges from 85.6 -77.3%; 86.1-79.4% and 86.6-80.6% respectively, during the storage period. However, carbohydrate content increase due to processing as compared to the raw material and was similarly reported (Ezeocha and Ojimelukwe, 2012; Ojokoh and Gabriel, 2010) [22, 10]. The increase may be due to absorbing water to bulk up via cross linking reaction probably induced by heat generated during boiling. This may increase the stability of the carbohydrate thereby enhancing resistance to further heat (Nzewi and Egbounu, 2011) [21]. The decreased in the carbohydrate content of the samples after storage collaborates the finding of Oyeyiola *et al.* (2014) [25]. Carbohydrate content of the samples might have decreased because of its utilization for growth by the microorganisms' present.

3.1.2.1 Starch and Total Sugar
It is observed that from 0day onward Starch content was high in T3 (39.1%) followed by T2 (38.4%) and T1 (37.5%) the least. Total sugar content was also high in T3 (3.7%) and least in T1 (3.1%). The starch and total sugar content showed decreasing trend during the storage period. After 4month storage, the starch and sugar content of T3 was still the highest which are 27.5% and 2.2%, respectively while the least in T1 with values 24.7% and 1.7%. T3 showing higher starch content and total sugar which might be due to increased dehydration temperature (60 ^{0}C) showing a higher breakdown of polysaccharide (starch) to mono and disaccharide unit (total sugar). Reduction in the Starch and total sugar content of the samples during storage might be because of its utilization for the growth of microorganisms' present. The starch and sugar increases during processing as compared to the raw sample and was similarly reported by Adegunwa *et al*. (2011) [2].

3.1.3 Protein
The result showed that from 0 days onwards Protein content was high in T1 (1.23%) followed by T2 (1.19%) and least in T3 (1.17%). Lower protein content in higher temperature might be due to protein denaturation at a higher temperature. The protein content of yam chips decreases during storage. After 4-month storage, the protein content in T1 (1.03%) was still higher than T3 (0.91%) while T2 (0.97%) remains moderate. Reduction in protein content during processing may be as a result of the loss of free amino acids which took place during blanching (Ezeocha and Ojimelukwe, 2012) [10]. The result of decreases in Protein content during storage corroborates the findings of Amusa (2001) [5] and Ojokoh and Gabriel (2010) [22].

3.1.4 Fat
There is no significant difference in Fat content of the yam chips with respect to temperature treatment, which might be because of used of single variety and the fact that yam tubers content low fat (<1%) as of Polycarp *et al*. (2012) [26], Adegunwa *et al*. (2011) [2] and Osagie and Eka (1998) [24]. Fat content in T1, T2 and T3 ranges from 0.17-0.11%, 0.16-0.09% and 0.14-0.08%, respectively.
Processing reduces the fat content and also further decreases, though very slightly during storage occurs in all the samples. This was in agreement with earlier reports of Ezeocha and Ojimelukwe (2012) [10], Amusa (2001) [5] and Ojokoh and Gabriel (2010) [22]. Most moulds have high lipolytic activities, therefore fats are broken down into fatty acids and partial glycerides during fungal deterioration of stored products.

3.1.5 Vitamin c
Vitamin C content was high in T1 (5.7mg/100g) and low in T3 (4.4mg/100g) samples. The reason of decrease in Vitamin C content at high-temperature samples might be due to increase in oxidation at higher temperature. During storage, Vitamin C content still decreases because oxidation continued during storage at room temperature. The value of T1 (2.8%) was still high among the samples at the end of storage.

3.1.6 Beta-Carotene
There is no significant difference in Beta-carotene content as shown in Table no.1, of the yam chips with respect to temperature treatment which might be because of used of single white colour flesh cultivar. Though the samples have low beta-carotene content, at 0 days the value was high in T1 (0.19mg/100g) and low in T3 (0.16mg/100g) which decreases linearly during storage with values 0.09md/100g and 0.05mg/100g respectively, at the fourth month which might be because of microbial activity during storage at room temperature.

3.1.7 Antioxidant activity and Phenol
Lower temperature treated sample i.e. T1 have high

antioxidant activity and phenol content than higher temperature treated samples. The antioxidant and phenol content of T1 at 0 day was 19.4% and 24.3mg/100g which is the highest among the samples and the least i.e. T3 is 15.5% and 20.2mg/100g, respectively. Reduction in both antioxidant activity and phenol content with increasing heating temperature was also observed by Yi and Kuo (2007) [33]. Furthermore, antioxidant activity and phenol content decreases during storage were at the end of storage T1 is still the highest with values 7.5% and 15.3 mg/100g, respectively, these decreased might be because of continuous oxidation that occurs during storage resulting in the browning of the samples.

3.1.8 Tannin

The tannin content varies significantly in the prepared yam chips samples. The tannin content was high in T1 (2.6mg/100g) and low in T3 (2.2mg/100g) during 0day and then decreased linearly during storage with corresponding value 1.7mg/100g and 1.4mg/100g, respectively at the fourth month. This result was similar to the finding of Ezeocha and Ojimelukwe (2012) [10] and Adegunwa *et.al.* (2011) [2] where tannin content lowers due to processing which might be due to the thermal degradation and denaturation of the tannin as well as the formation of insoluble complexes (Kataria *et al*., 1986) [15]. Since tannin binds to protein and iron thereby reducing its bioavailability (Liener, 1980) [17] low tannin content is considered to be good.

3.1.9 Trypsin Inhibitor

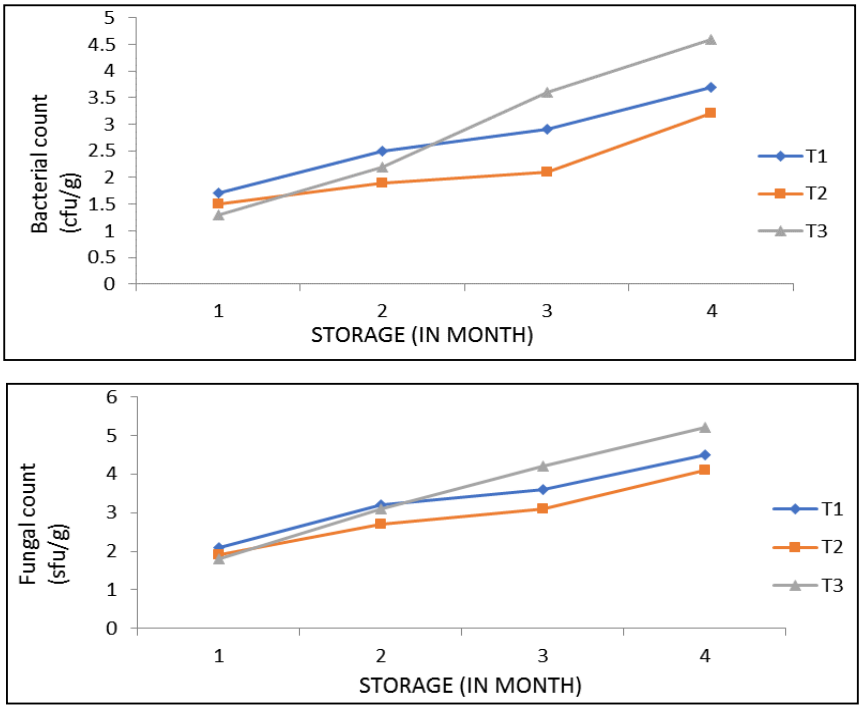
Trypsin inhibitor activity (TIA) was low in all the samples but showed the significant difference from the 0 days onwards. T1 (0.22 mg/g) shows high TIA while T3 (0.16 mg/g) the least. During the storage duration, TIA tends to decrease with values 0.15mg/g and 0.1mg/g for T1 and T3, at the end of storage. These observations clearly showed that processing (blanching and dehydration temperature) results in inactivation of this enzyme inhibitor of yam tuber and higher the temperature more the inhibiting ability. This is in agreement with the finding of Megh and Kawabata (2006) [18] in yam tubers where cooking results in complete inactivation (90-95%) of this enzyme inhibitor and Sasikiran and Padmaja (2003) [30] in sweet potatoes when heating at a temperature above 80^0C. Heat-labile nature of trypsin inhibitors suggests that they can be inactivated during cooking (Prathibha *et al.*, 1995) [27] indicating that trypsin inhibitors may not interfere with digestion if tubers are properly cooked before consumption. Therefore, reduction in TIA is desirable and is expected to enhance protein digestibility.

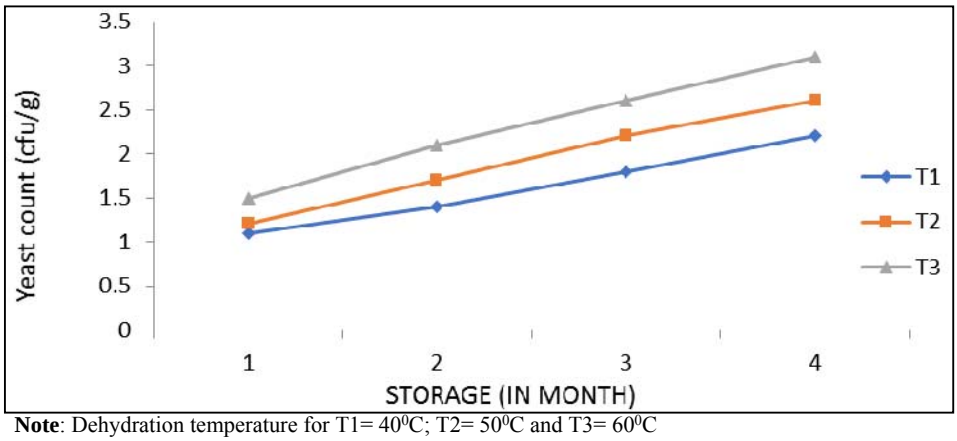
3.1.10 Oxalate (total oxalate, water soluble oxalate and calcium oxalate)

From Table no.1, it is observed that total oxalate and water-soluble oxalate varies significantly while calcium oxalate does not vary significantly in all the samples. From 0 day, onwards T3 (0.11 mg/100g) treatment contain low total oxalate content while T1 (0.14 mg/100g) the highest. T3 was also correspondingly low in water-soluble oxalate (0.11 mg/100g) and calcium oxalate (0.11 mg/100g). During storage, the oxalate content decreases. Processing reduces the oxalate content which might be due to its solubility during blanching. These are in agreement with the report of Albihn and Savage (2001) [20] which states that boiling may cause considerable skin rupture and facilitate the leakage of soluble oxalate into the cooking water and caused its reduction. Megh and Kawabata (2006) [18] investigate the effect of different domestic cooking methods (boiling, pressure cooking and baking) and reported that the average reduction ranges on cooking were 10-45 % for oxalate. Oxalate can have a deleterious effect on human nutrition and health, particularly by decreasing calcium absorption and aiding the formation of kidney stone (Noonam and Savage, 1999) [20]. Therefore, reduced oxalate content could have a positive impact on the health of consumers thereby enhancing the bioavailability of essential dietary minerals.

3.1.11 Microbial Count

Table no.2 and Fig.1 showed the microbial count of the yam chips.





Note: Dehydration temperature for T1= 40^{0}C; T2= 50^{0}C and T3= 60^{0}C

Fig 1: Microbial (Yeast, Fungal and Bacterial) count of the yam chips and its changes during storage.

3.1.11.1 Bacterial count

At 0day T1 has low bacterial count while high in T3 which might be due to high phenol content in T1. But later during storage the bacterial count increases which might be also related to moisture content. T2 showed the lowest bacterial count from the second month till the end of storage. The phenolic compounds have been reported to have multiple biological effects including antioxidant activity and antibacterial (Shui and Leong, 2002) [31].

3.1.11.2 Fungal count

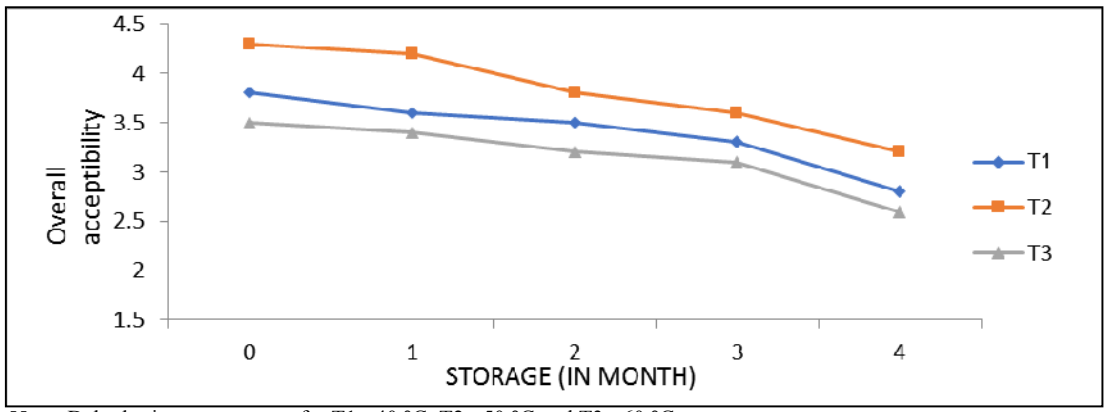
It is observed that at 0day T1 showed high fungal count while low in T3 which might be due to higher moisture content. During storage, the fungal count increases in all the samples. At the end of storage, T2 showed the least fungal count. Adenji (1996) reported that fungal growth in agricultural produce is directly correlated to the moisture content.

3.1.11.3 Yeast

The result showed that at 0day T3 shows high yeast count while low in T1 which might be related to the sugar content. Later during storage, the yeast count increases correspondingly.

3.1.12 Sensory Attribute

The sensory attribute was evaluated on a 5-point scale where 1 = disliked very much, 3 = liked moderately and 5 = liked very much. Table no.3 and Fig.2, showed the result of the hedonic scale test, it is observed that the overall acceptability in terms of colour and texture of the yam chips sample were significantly different ($p>0.05$) from each other. The overall acceptability decreases with storage. T2 (4.3) has the highest overall acceptability from 0 day onward till the end of storage while T3 (3.5) has the lowest overall acceptability which could be due to the brittle texture and brownish dull appearance.



Note: Dehydration temperature for T1= 40 °C; T2= 50 °C and T3= 60 °C

Fig 2: Sensory attribute of the yam chips and its changes during storage.

4. Conclusion

Therefore, from the above results, it can be concluded that dehydration at 50 ^{0}C, for (12±2) hrs. is the best for storing yam chips with negligible change in nutrients, microbial and sensory attributes up to 3 months. Higher the dehydration temperature above 50 ^{0}C, higher is the loss of nutrients and lowering the dehydration temperature below 50 ^{0}C, more is the moisture content which in turn result to more microbial growth. During storage, all the yam chips showed a gradual decrease in composition, due to absorption of moisture, with increasing storage time. The quantity of most of the anti-nutritional factors decreases while some of the major nutrients like total carbohydrate, total sugar and starch increases during processing of chips than the raw tubers. Therefore, processing of yam tubers into chips can be recommended and add variety to our diet.

5. Acknowledgement

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References: References to the literature cited for the manuscript should be numbered in order of appearance in the manuscript and cited in the text with superscript numbers. The reference number should follow the following format.

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Panda BB, Gaur K, Kori ML, Tyagi LK, Nema RK, Sharma CS *et al*. Anti-Inflammatory and analgesic activity of *Jatropha gossypifolia* in experimental animal models. Journal of Pharmacology 2010; 3(9):1-5.

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