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Comparative Analysis of the Performance of a Retrofit Vacuum Refrigeration System with Local Vegetable Products

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Abstract:- Large quantity of food substance and vegetable products are lost in Nigeria due to poor storage conditions leading to high post-harvest losses which negatively impact on the contribution of the agricultural sector to the Nigerian economy. Development of an effective storage medium against the activities of organism that promotes the enzymatic decomposition of fragile vegetable food substances in Nigeria continued to pose some challenges. The comparative performance evaluation of a Developed Vacuum Refrigeration System (DVRS) and Vapour Absorption Refrigeration System (VARS) on the storage life of pumpkin leaves was carried out. Proximate analyses (PA) was carried out on pumpkin leaves to determine its initial nutritional value, the degradation of the nutritional components was monitored every seven days for a period of 28 days through repeated PA test. A sensory evaluation was also carried out during the period of storage. The results indicate that the moisture content and fibre content degraded from 3.42 % to 3.01 % and 0.78 % under the VRS and VARS storage respectively, the VRS could sustain the nutritional value of the leaves by about 88.85% while the sustenance under VARS is 44.99%. The sensory evaluation considered the pumpkin leaves in good condition and acceptable under the VRS storage and bad and rejected under VARS under 28 days of storage. The results established the capability of the VRS in sustaining the nutritional components of pumpkin leaves to 28 days post-harvest with the potentials to enhancing the contribution of the agricultural sector to the Nigerian economy.

Keywords:- *Vacuum, Refrigeration, Pumpkin Leaves, Proximate Analysis, Vegetable, Agricultural*.

I. INTRODUCTION

The Nigerian agricultural sector is characterized by bountiful harvest of fruits, vegetables, and livestock annually, due to favorable climatic conditions. Large numbers of these products are wasted due to the absence of effective preservation methods [1]. The nature of these food substances, especially fruits and vegetables, is so precarious that deterioration sets in after a few days postharvest. The implication is that even when used in this period; the nutritional value of the food would have largely degraded [2]. It was estimated that post-harvest losses were close to N9 billion in 2017 in Nigeria [3].

An emerging means of products and food storage is the use of vacuum technology. It is a swift evaporative cooling process for porous and moist food substances. Vacuum cooling has been adopted by some food manufacturers to enhance the quality and competitiveness of their products in developed countries [4]. It is particularly used for preserving vegetables and lettuce which cannot ordinarily be refrigerated for a long time using the conventional vapour absorption system refrigeration (VASR) [5].

[6] used vacuum storage to extend the shelf of processed carrots at 40 ^{0}C for seven days while preserving the defining properties of the vegetable. In further investigation, [7], demonstrated that vacuum storage can help significantly to maintain the three main properties of the vegetables of texture, color and flavor. [4] carried out a comparative analysis of vacuum cooling and the conventional cooling techniques on meatball to demonstrate the vacuum pressure effect on the cooling time, the temperature decrease and microbial growth rate. [8] demonstrated the inherent advantages and disadvantages of the vacuum cooling process in comparison to the air cooling for small meat slices.

In Nigeria, several authors have investigated the role of microbial contamination of fruits and vegetables and their consequences on public health and the profitability of the farmers [9]; [5]; [3]). [10] investigated the role traditional banana ripening can play in increasing its shelf life, [3] investigated the effects of electromagnetic radiation on fungi causing spoilage of locally produced fruits and vegetables in Nigeria.

But there are no adequate research works in Nigeria and Sub-Saharan Africa countries that explore the benefits of vacuum refrigeration system in pursuit of increasing the shelf life of locally produced fruits, vegetables, and processed foods.

There is the essential to develop a versatile local storage system that can increase the shelf life of vegetables and other associated products to enhance their availability over time in the year and encourage their mass production to enable the Nigeria populace access the their health benefits and enhance the profitability of farmers in the agricultural sector.

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In addition, in spite of the fact that vacuum refrigeration system (VRS) has the capacity to enhance shelf life of many food products, the regulation of the storage parameters in adequate and variable mix in accordance with the intrinsic storage requirements of some particular food continue to be a challenge. It important to develop a modified VRS capable of sensing and regulation of refrigeration storage parameters in adequate variable mix to adapt the storage chamber to the intrinsic storage characteristics of fragile agricultural products and processed food. In this study, a comparative performance evaluation was carried out for the developed vacuum refrigerator and VASR. Pumpkin leaf was chosen as a case study due to its very fragile nature and high nutritional value that makes it a special delicacy in the Nigeria food market [11].

II. MATERIALS AND METHODS

The comparative performance of the developed VRS was analyzed through the storage of prepared samples of pumpkin leaves in the vacuum refrigerator and VASR for 28 days. Proximate analysis was carried out on the pumpkin leaves to determine its initial nutritional value which was then monitored through the storage period in both the VASR and vacuum refrigeration processes. Established optimum conditions of vegetable preservation were used as a guide and the capability of the developed VRS to provide optimum mix of the storage parameters was utilized.

A sensory evaluation of the preserved samples was also periodically carried out during the period of storage by a team of selected nutritionist using factors as smell, appearance and texture as reference factors.

The Analysis of Variance (ANOVA) was used to established the capability of the refrigeration systems to sustain the nutritional value of the pumpkin leaves during the period of storage.

- *Pumpkin Leaf (Cucurbita moschata)*

Pumpkin leaf is a dark green leaf that is fortified with essential minerals and possess high nutritional value [12]. Apart from being a delicacy across the world, it is also used for therapeutic and medicinal applications. The leaves are round, large and lobed. It has several originating vane from the same point. Dark green, light green, grayish green and yellow variety of pumpkin leaves are available. Pumpkin leaves deteriorates rapidly after harvest and degraded rapidly in some few days post harvest.

- *Vacuum Refrigeration System*

The vacuum refrigeration system is unique in providing a vacuum over stored materials under low temperature and relative humidity. The combination of these factors eliminates the moisture and oxygen which are primary elements that facilitates degradation of food substances.

The developed vacuum refrigerator is enhanced with a programmable digital control and automation to maintain the vacuum at optimum condition that conforms to the best characteristic temperature, pressure and relative humidity of the specific product storage. The programmed control system is equipped with a humidity and temperature sensor, and pressure control valve. Through these facilities, it regulates the refrigerated vacuum parameters in accordance with optimum storage characteristics of the stored product.

- *Specimen Preparation and Storage*

Fresh pumpkin leaves were sourced from Uchi Central Market, Auchi, Edo State, washed clean and aerated to remove the surface moisture. 40g of the sample were stored in plastic containers in the vacuum refrigerator and VARS over the storage period. The optimum condition of storage of pumpkin leaf 15^0C and 60% relative humidity [13], was targeted for the storage process.

- *Chemical Analysis*

The proximate analysis was carried out on the local pumpkin leaves sample to determine its initial nutritional value. The degradation of the nutritional content of the leaves due to enzymatic decomposition was monitored by extracting 5g of the samples from the vacuum refrigerator and VARS storage with the analysis repeated every seven days for 28 days. The documented results from the weekly proximate analysis test are shown in Table 1 and 2.

III. RESULTS AND DISCUSSION

The result of the initial proximate analysis of the pumpkin leaves is shown in Table 1. The result is in agreement with the study of [14]. The minor variation may be due to local climatic conditions.

Table 1: Proximate Analysis of 5g of Local pumpkin Leaf

Parameter	Composition
Moisture content	3.42 %
Crude protein	6.35 %
Crude lipid	5.25 %
Crude fibre	2.15 %
Carbohydrate	72.25 %
Ash	10.01 %
Energy value	368.90 kcals

The results of the subsequent proximate analysis of pumpkin leaves placed under vacuum refrigeration and VARS storage for 28 days are shown in Table 2 and 3.

Table 2 indicates the progression of the degradation of the nutritional value of the pumpkin leaves under vacuum refrigeration storage. It is indicated that the loss in moisture content is 11.99% for 28 days, crude protein is 12.60%, crude lipid is 17.00% and crude fibre is 18.40%. Carbohydrate, ash content and energy value are 12.40%, 0.016% and 12.50% respectively. While other parameters decreased slightly, there was a slightly increase in ash content value of 0,16% which is agreement with the study of [15]. The results indicate that there was no significant degradation of the nutritional value of pumpkin leave under VRS storage in the period of study.

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Table 2: Degradation of Nutritional Values of Pumpkin leaf Under Vacuum Refrigeration Storage

	Nutritional degradation (Days)					Average Degradation	Percentage Degradation
Parameter	**1**	**7**	**14**	**21**	**28**		
Moisture content	3.42	3.40	3.35	3.27	3.01	3.296	11.99
Crude protein	6.35	6.305	6.151	5.92	5.750	6.094	12.60
Crude lipid	5.250	5.150	5.053	4.982	4.360	4.926	17.00
Crude fibre	2.150	2.101	2.050	1.820	1.76	1.624	18.40
Carbohydrate	72.250	72.150	70.150	67.060	63.318	69.156	12.40
Ash	10.010	10.110	10.180	10.25	10.280	10.166	0.016
Energy value	368.900	369.580	354.675	342.339	322.787	351.560	12.50

Table 3 indicate the degradation of the nutritional parameters of pumpkin leaves under VARS storage. The results indicate a significant reduction in the moisture content by 77.20%. The degradation of crude protein, fibre and lipid are 62.20%, 68.20% and 59.50% respectively. Carbohydrate and energy value are 60.60% and 61.40% respectively. The ash content increase slightly by 5.60%. The results indicate a more severe degradation of the nutritional value of the pumpkin leaves under VARS storage than vacuum storage. The loss of moisture was very high leading to severe warping of the leaves.

Table 3: Degradation of Nutritional Values of Pumpkin leaf Under VARS

	Nutritional degradation (Days)					Average Degradation	Percentage Change
Parameter	**1**	**7**	**14**	**21**	**28**		
Moisture content	3.42	2.080	1.28	1.010	0.780	1.714	77.200
Crude protein	6.35	5.48	4.880	3.578	3.27	4.712	48.50
Crude lipid	5.250	4.80	3.81	2.981	2.375	3.843	54.476
Crude fibre	2.150	1.98	1.57	1.315	1.057	1.614	50.82
Carbohydrate	72.250	68.157	59.968	45.356	36.467	56.440	49.52
Ash	10.010	10.112	10.320	10.410	10.580	10.226	5.60
Energy value	368.900	347.87	326.187	275.584	186.211	300.950	49.52

Figure 1 represents the comparative analysis of the degradation of the nutritional parameters of the pumpkin leaves under the two refrigeration storage. The additional loss of moisture under VARS storage is 65.21%, while carbohydrate and energy have additional loss of 48.20% and 48.90% respectively. Analysis of the percentage loss spectrum indicates higher nutritional values and degradation losses of pumpkin leaves under the VARS.

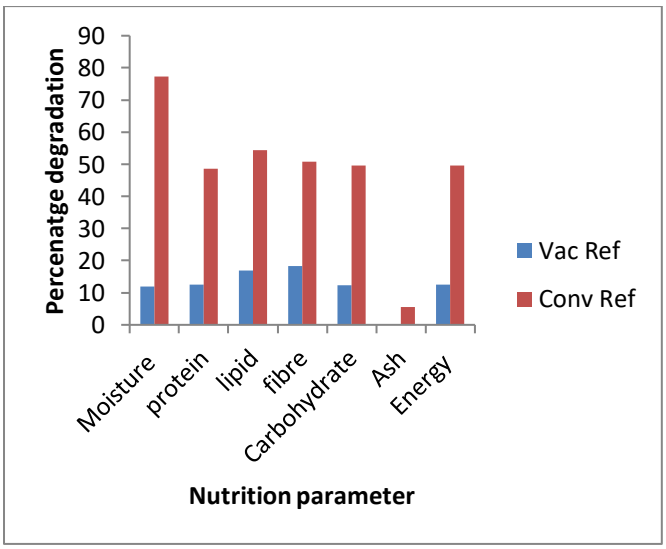

Fig 1: Comparative Performance Analysis of Vacuum and Conventional Refrigeration Storage of Pumpkin leaf

Figure 2 and 3 indicated the profile of the comparative loss of moisture content and degradation of carbohydrate. The moisture content decreased from 3.42% to 3.01% under VRS. The results indicated that 88% of the moisture content was retained in the leaves which preserved the texture, color and overhaul quality of the product.

The decrease under VARS was from 3.42% to 0.78% representing 77.20% loss of original moisture content. which lead to severe warping, loss of texture and dryness of the leaves. Most of the loss of moisture took place within 14 days of storage.

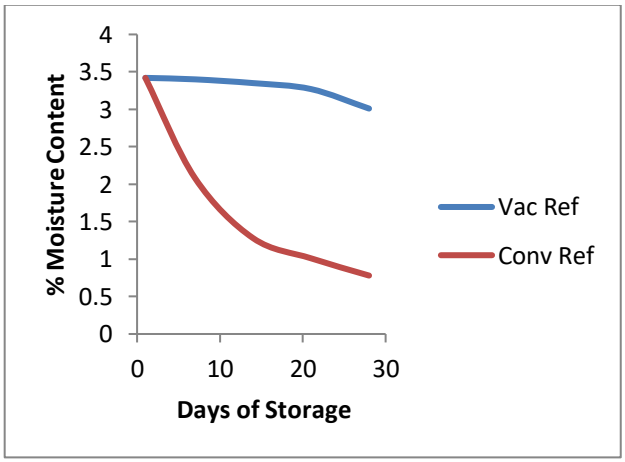

Fig 2: Comparative Plot for Loss of Moisture Content in Storage

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The carbohydrate content degradation is indicated in Figure 3. Under the VRS the carbohydrate content slightly degraded from 72.250% to 63.318% in 28 days, sustaining about 88% of the carbohydrate content. Other nutritional parameters were also sustained around this range with the exception of fibre with degraded by 18.20%.

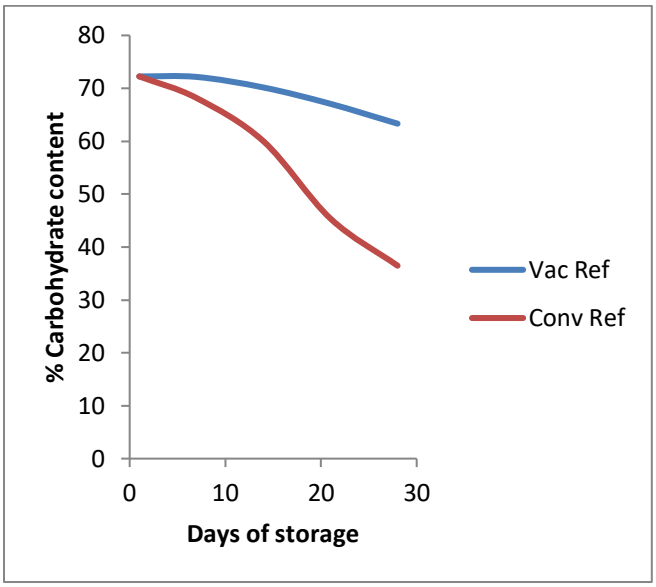

Fig 3: Comparative Plot for Carbohydrate Degradation in Storage

The carbohydrate content under VARS storage degraded from 72.250% to 36.467% representing 49.52% loss of original carbohydrate content. Other nutritional parameters generally degraded by about 50% with the exception of the moisture content. The ash content increase slightly both under the VRS and VARS.

The stored samples of pumpkin leaves were subjected to sensory evaluation from a team of 10 nutritionist using factors of smell, color and texture as quality guide to determine their acceptability and satisfaction for consumption.

The ranking for the assessment is indicated in Table 4 , while the outcome of the assessment is indicated in Table 5.

Table 5: Sensory Assessment Ranking

Assessment	Ranking
Very good	05
Good	04
Acceptable	03
Fair	02
Manageable	01
Bad	00

Majority of the nutritionist considered the pumpkin leaves in good condition after 14 days of storage and acceptable after 28 days of storage under VRS as shown in Table 6. This indicate the satisfactory extension of the shelf life of pumpkin leaves from a few days to 28 days.

Table 6: Percentage Sensory Evaluation Ranking of Pumpkin Leaves in VRS Storage.

	Sensory Evaluation (Days)				
	1	**7**	**14**	**21**	**28**
Very good (%)	100	50	-	-	-
Good (%)	-	50	70	40	-
Acceptable (%)			30	60	60
Fair (%)					40
Manageable (%)					
Bad (%)					

The majority of the assessors considered the leave manageable after 7 days of storage and bad at 21 days of storage under VARS as indicated in Table 7. The leaves became warped, very dry, lost their texture and unsightly. This change of condition started at about 4 days of storage.

Table 7: Percentage Sensory Evaluation Ranking of Pumpkin Leaves in Convectional Refrigeration Storage

	Sensory Evaluation (Days)				
	1	**7**	**14**	**21**	**28**
Very good (%)	100	-	-	-	-
Good (%)	-	-	-	-	-
Acceptable (%)	-		-	-	-
Fair (%)	-	20	15	-	-
Manageable (%)	-	80	85		-
Bad (%)	-	-	-	100	-

The proximate analysis and sensory evaluation are in agreement with the view of [5]Erena (2020) that the VARS is not effective for vegetable shelf life storage.

The *p* value of the ANOVA carried out on the proximate analysis of the VRS is 1 which indicated that there is no significant difference between the nutritional value of the pumpkin leaves under vacuum refrigeration storage within 28 days. This indicates the effectiveness of the vacuum refrigeration in sustaining the nutritional value of the product for the period of storage.

The *p* value of the VARS is 0.984 which indicated that the VRS has a higher capacity to sustain the degradation of pumpkin products under storage compare to the VARS. This also indicated that the VARS was effective to an extent in sustaining the nutritional value of pumpkin leaves by about 50% with the exception of the moisture content as indicated in Table 3. The effect of the large loss of moisture content rendered the pumpkin leaves under VARS storage unsightly and graded bad under 14 days.

IV. CONCLUSION

Comparative performance evaluation of the developed vacuum refrigeration system and VARS was carried out to determine the capacity of the refrigeration systems to sustain the nutritional value of the pumpkin leaves over a period of storage of 28 days. A complementary sensory evaluation process by a team of nutritionist was also done to assess the

visual acceptability of the vegetable after the period of storage.

It was observed that there was a slight loss of the moisture content of the leaves from 3.42% to 3.01% under vacuum refrigeration storage while there was significant loss from 3.42% to 0.78% under VARS. This represents an additional loss of 65.21% under VARS storage which lead to severe warping of the vegetables. The average nutritional degradation under VRS and VARS are 14.15% and 55.01% respectively. This indicate that the VRS could sustain the nutritional value of the leaves by about 88.85% while the sustenance under VARS is 44.99%. The sensory assessment considered the vegetables acceptable for consumption for the VRS and bad for the VARS at 28 days.

The VRS is effective in sustaining the nutritional values of the pumpkin leaves in spite of its very fragile and easily perishable nature due to its capability and flexibility to sense and regulate the storage parameters in adequate and variable mix by the temperature and humidity controls systems. This performance indicate that the VRS is capable of sustaining the nutritional value of most fragile and perishable food substances and should be adopted in in the preservation of perishable agricultural products to enhance their shelf life for increased access to the nutritional value of perishable agricultural products. The developed VRS is capable of significantly enhancing the profit profile and competitiveness of perishable agricultural products in Nigeria.

REFERENCES

[1]. Yahaya, S. M. and Mandiya, A. Y. (2019). Review of post harvest losses of fruits and vegetables, Journal of Scientific and Technical Research, 13(4). 10.26717/BJSTR.2019.13.002448

[2]. Bastrash, S., Makhlouf, J., Castaigne, F., and Willemot, C., (2013). Optimal Controlled Atmosphere Conditions for Storage of Broccoli Florets. *Journal of Food Science,* 58, 338 – 341.

[3]. Akinyele, B. J., Akinkunmi, O. C. and Adedayo, K. D. (2021). Effect of electromagnetic field on the spoilage fungi of some selected edible fruits in southwestern, Nigeria. *Journal of Microbiology, Biotechnology and Food Sciences*, 701-712.

[4]. Ozturk, H. M., Ozturk, H. K, Koçar G. Microbial analysis of meatballs cooled with vacuum and conventional cooling. J Food Sci Technol. 2017 Aug;54(9):2825-2832. doi: 10.1007/s13197-017-2720-7. Epub 2017 Jun 14. PMID: 28928522; PMCID: PMC5583112.

[5]. Erena, N. B. (2020). Isolation and characterization of pathogenic bacteria associated with rotten tomatoes sold at Tungan Goro Market, Minna. Niger State, Nigeria. *Life Science Journal*, *17*(2), 1- 4.

[6]. Rocha, A., Mota, C., and Morais, A. (2007). Physico-chemical qualities of minimally processed carrot stored under vacuum. *Journal of Foodservice,* 18, 23-30.

[7]. Spokowski, A., (2010). Effect of refrigerated vacuum storage on the shelf life of comingled broccoli, cauliflower, and carrots, Master of Science Thesis, Clemson University.

[8]. Schmidt FC, Silva ACC, Zanoelo E, Laurindo JB. Kinetics of vacuum and air cooling of chicken breasts arranged in stacks. J Food Sci Technol. 2018 Jun;55(6):2288-2297. doi: 10.1007/s13197-018-3146-6. Epub 2018 May 2. PMID: 29892129; PMCID: PMC5976614.

[9]. Oyedele, O.A., Kuzamani, K.Y., Adetunji, M.C., Osopale, B.A., Makinde, O.M., Onyebuenyi, O.E., Ogunmola, O.M., Mozea, O.C., Ayeni, K.I., Ezeokoli, O.T. and Oyinloye, A.M., (2020). Bacteriological assessment of tropical retail fresh-cut, ready-to-eat fruits in south-western Nigeria. *Scientific African*, *9*, 50 - 57.

[10]. Ikhajiagbe, B., Ogochukwu, O.F. and Ogwu, M. C. (2021). Shelf Life, Fruit Quality and Safety of Banana (Musa Species) Ripened through Traditional Ripening Techniques in Nigeria. *International Journal of Fruit Science*, *21*(1), 66 - 81.

[11]. Ashiq Hussain, Tusneem Kausar, Sawera Sehar, Ayesha Sarwar, Muhammad Yousaf Quddoos, Jawed Aslam, Atif Liaqat, Tahira Siddique, Qurat Ul An, Samina Kauser, Abdul Rehman and Rizwan Nisar A review on biochemical constituentsof pumpkin and their role as pharma foods; a key strategy to improve health in post COVID 19 period, *Food Production, Processing and Nutrition (2023) 5:22*, https://doi.org/10.1186/s43014-023-00138-z

[12]. Mashitoa, F. M, Manhivi V, Slabbert, R. M, Shai, J. L, Sivakumar, D. (2021). Changes in antinutrients, phenolics, antioxidant activities and in vitro α-glucosidase inhibitory activity in pumpkin leaves (*Cucurbita moschata*) during different domestic cooking methods. Food Science and Biotechnoly. 30(6), 793 - 800. doi: 10.1007/s10068-021-00916-w. PMID: 34249384; PMCID: PMC8225750.

[13]. Center of Agricultural, Food and the Environment (2013). Pumpkin and winter squash harvest. Retrieved from UMass Amherst website: https//ag.umass.edu

[14]. Fai F.Y Danbature W.L; Auwal Yahaya and Usman Y.M. (2013). Proximate and some Mineral Analysis of Pumpkin (Cucurbita Maxima) Leaf, Journal of Physical Sciences and Environmental Safety 3(1), 9 – 16.

[15]. Osman M., Abdalla M. and Mohamed N. S. (2009). Effect of storage period on chemical composition and sensory characteristics of vacuum packed white soft cheese, Pakistani Journal of Nutrition, 8,145 - 147