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EFFECTS OF POSTHARVEST MANAGEMENT ON THE NUTRIENT CONTENT OF POTATO (*SOLANUM TUBEROSUM*) TUBERS DURING STORAGE

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Abstract

An experiment was performed to assess the effect of two plant powders and six storage methods on the proximate composition of potato tubers stored under ambient conditions to find a simple technology for storing potato tubers with a minimal nutrient degradation to reduce postharvest losses by smallholder farmers. Two plant powders and six storage methods were used in the study, which was designed as a 3 x 6 factorial experiment laid out in a completely randomized design *(CRD)* and replicated three times. The application of neem leaf powder to potato tubers and storage in the pit significantly ($P \leq 0.05$) maintained protein (5.65%), fat (0.91%), fiber (0.75%), ash (2.70%), dry matter (30.63%), moisture (69.34%), and carbohydrate (20.62%) contents. Similarly, the pit storage method has influenced the nutrient content significantly ($P \leq 0.05$) and is the best method for retaining protein (5.74%), fiber (0.78%), ash (2.81%), and moisture (69.83%) contents of potato tubers during storage under ambient conditions, and there is no significant ($P > 0.05$) interaction effect between the plant powder and the storage method. The study has found that the neem leaf powder and the pit storage significantly preserved the nutrient content of potato tubers during the four weeks of storage, which helped minimize postharvest losses.

Keywords: basket, carton, floor, ginger, jute bag, neem, pit, polypropylene bag

INTRODUCTION

Potato (*Solanum tuberosum*) is the most consumed root crop and the fourth major food crop in the world after wheat, rice, and corn (Ayalew et al., 2014; Ahmed, 2023). Globally, the world output of potatoes is set at 359.07 million metric tons in 2020 (*FAOSTAT*, 2022). It is also a means of improving the livelihood and food security of a nation due to its high productivity per area and the short production time (Tolessa, 2018). Africa accounts for 17,625,680 tons, and Nigeria is currently the fourth largest producer in Sub-Saharan Africa with an annual production of 843,000 metric tons (*FAOSTAT* 2022). In addition to being a major source of food and livelihood, potatoes are also used as a raw material for beverages, feeds, and industrial products like starch and adhesives, as well as for the manufacturing of papers and boards (Devaux et al., 2020). Other industries are exploring the possibilities of using potato waste to obtain polylactic acid for plastic products, and researchers are also seeking ways to use starch as a base for biodegradable packaging materials (Ahmed, 2022).

Nutritionally, potatoes consist mainly of carbohydrates and essential nutrients like protein, minerals, vitamins, and, most importantly, antioxidants (Bembem and Sadana, 2013; Zaman et al., 2014; Burgos et al., 2020). A fresh potato tuber at harvest contains 80% water and the remaining 20% is dry matter, while 60% to 80% of the dry matter consists of starch with sugar content (Brar et al., 2017; Tolessa, 2018. Nutritionally, it is considered a good source of many vitamins (B, C, E, K, folic acid, and carotenoid), minerals (K, Mg, Fe, Cu, P) and antioxidants (polyphenols and flavonoids) with a proximate composition of 78% water, 1.9% protein, 20.1% carbohydrates, 0.9% sugar, 1.8% fiber and 0.1% fat with high content of calories (Tolessa, 2018; Burgos et al., 2020). In addition, potato contains dietary fiber (cellulose, hemicelluloses, pectin and lignin) that plays an important role in human nutritional requirements (Devaux et al., 2020). Potato has a high nutritive value due to its protein content which consists of a high percentage of amino acids such as lysine, leucine, phenylalanine, threonine, and valine.

According to Dandago & Gungula, (2011); Ezeocha & Ironkwe, (2017) and Ahmed, (2023) storage has had a highly significant effect on the carbohydrate composition of potatoes, but it had no significant effect on the other nutrient content. However, Khanal & Uprety (2014) observed that storage influences the physicochemical properties of potatoes. According to Haider et al. (2022), storage affects the proximate composition like moisture, ash, protein, and carbohydrate content, even though it had no significant effect on the fat and fiber content of the potato. Sugri et al. (2017) also reported similar findings on the nutritive deterioration of sweet potato tubers caused by storage.

The major problem facing the potato industry is huge postharvest losses (Awojobi, 2004; Devaux et al., 2020), particularly in tropical regions where temperatures are high and there are no cold storage facilities (Dandago & Gungula, 2011; Ahmed et al., 2022). In Nigeria, as much as 40 % of the stored potatoes deteriorate within three months of storage caused by poor storage methods (Okonkwo et al., 1988). The storage of tubers in sacks under the hot tropical sun and unventilated stores at marketplaces further increase tuber losses due to physiological and microbial deterioration (Ugonna et al., 2013; Ahmed et al., 2023). Storage of potatoes requires specialized care in cold warehouses (Ezeocha & Ironkwe, 2017; Ahmed et al., 2023), but despite the progress made in potato production in Nigeria, there are still some constraints that limit its postharvest management, processing, and marketing. These include inadequate storage facilities, poor postharvest management, and a lack of technical knowledge, which affect the yield, shelf life, and value addition of potatoes (Ugonna et al., 2013;Wichrowska, 2022). The use of chemicals for both disease control and dormancy extension has not been successful even in developed countries, where trials with hypochlorite, chlorine dioxide, 5-nitro-8-hydroxyquinoline, glyphosate, etc. were conducted to eliminate microbial losses and extend shelf life during storage (Dandago & Gungula, 2011; Ahmed et al., 2022). However, the hazards involved in using these chemicals, associated with their high cost and inaccessibility by poor farmers, make the search for alternative plant-based control (Tirosele et al., 2015; Sanon et al., 2017; & Ileke et al., 2020) and storage measures desirable. Hence the need to find a cheap and environmentally friendly method of extending the shelf life of potato tubers using plant extracts and simple storage methods. This study was conducted to determine the effects of these plant extracts (neem leaf and ginger powder) and storage methods (basket, pit, polypropylene bags, jute bags, corrugated fiberboard cartons, and floor) on the nutrient content of potatoes and also to determine the interaction effect between the plant extracts and the storage methods on the tubers' nutrient quality.

MATERIALS AND METHODS

Experimental Sites and Research Design

The experiment was conducted at the Postharvest Laboratory of the Department of Crop Production and Horticulture, Modibbo Adama University, Yola (9°14′-9°19′ N and

12°20′-12°30′ E). The average maximum temperature of the area can reach 40°C in April and a minimum of 18°C between December and January, with a mean monthly relative humidity of 27% in January and 83% in August. The area also has a mean annual rainfall of usually 700 to 1050 mm (Adebayo and Zemba, 2020). The treatments consisted of two plant powders and six storage methods (basket, pit, polypropylene bags, jute bags, corrugated fiberboard cartons, and floor), which were factorially combined to give a 3 x 6 experiment laid out in a completely randomized design (*CRD*) and replicated three (3) times.

Research Materials and Sample Preparation

Fresh potato tubers (Marabel cv) were purchased at the farm gate in Jos, Nigeria early in the morning and carefully transported to the laboratory to avoid physical damage to the tubers, while ginger and sawdust were all obtained at Jimeta main market and from sawmills in Yola, Nigeria. Neem leaves were collected within the premises of the university. Among the storage methods used in the research are the following: traditional baskets (15 x 15 x 25 cm), pit (60 x 60 x 60 cm), perforated polypropylene bags (112 x 67.5 cm), jute bags (112 x 67.5 cm), moist sawdust packed in corrugated fiberboard cartons (15 x 20 cm), and laboratory floor spread with sand (control). The plant powder was derived from neem leaves which contain alkaloids, flavonoids, phenols, saponins, tannins, terpenoids, and steroids, and ginger, which were shade-dried, and then ground to powder using a mortar and pestle, sieved using 20 µm and repeated until a fine powder was obtained. The powder was then applied uniformly on the tubers by shaking the tubers inside a bag containing the powder at a rate of 10 g per 20 pieces of potato tubers weighing 6kg before storage.

Laboratory Analysis

Proximate composition

The proximate composition was analysed using the AOAC (2020) protocol to determine ash, fat, moisture content, crude fibre, and crude protein using FOSStec™ (proximate analysis system Model 8200 made in Canada) as reported by Ahmed (2023).

a. Determination of percentage moisture content

The sample was dried in an oven for 4 hours at 70 – 80°C until the weight was constant and % moisture content was calculated using formula (1) as reported by Ijah *et al*. (2014) and Ahmed (2023) as shown below:

$$\%\ \text{moisture} = \left(\frac{\text{loss of weight}}{\text{weight of sample before drying}}\right)100 \qquad (1)$$

b. Determination of percentage ash contents

Five grams of the samples were accurately weighed using a sensitive electric balance, evaporated to dryness in an oven at 100°C and ashed in a muffle furnace at 550°C for 5 hours until they turned white or light grey, cooled in desiccators, and reweighed. The calculation was done using formula (2) as presented below:

$$\%\ \text{Ash (dry basis)} = \left(\frac{\text{Weight of ash}}{\text{weight of original sample}}\right)100 \qquad (2)$$

c. Determination of percentage crude fibre content

The starch and protein in the sample were dissolved by boiling the sample with acid (H_2SO_4) and later with NaOH using Fibretec™. The residue of cellulose and lignin was washed, dried, and weighed. The weight of the ash was subtracted from the weight of the residue. The calculation was done utilizing formula (3):

$$\%\ \text{crude fibre} = \left(\frac{\text{weight of sample used} - \text{weight of sample} + \text{crucible}}{\text{weight of sample used}}\right)100 \qquad (3)$$

d. Determination of percentage crude protein content

The micro Kjeldahl method of protein determination was employed using the Kjeltec™ digestion unit. The estimated nitrogen in the sample was subsequently converted to a percentage crude protein using the conversion formula (4):

$$\text{Crude protein} = \%\ \text{nitrogen} \times 6.25\ (\text{conversion factor}) \qquad (4)$$

e. Percentage dry matter content

Dry matter was determined by using the deduction method where the dry matter was obtained by subtracting the moisture content from 100%, i.e. the moisture content-free constituents. The calculation was carried out using equation (5):

$$\%\ \text{Dry matter} = 100\% - \text{Moisture content} \qquad (5)$$

f. Percentage fat content

Percentage fat content determination was done using the Soxhlet fat extraction method which was done by continuously extracting fat with a non-polar organic solvent such as petroleum ether for about one hour or more. The calculation of the percentage fat is done using equation (6)

$$\%\ \text{fat} = \left(\frac{\text{weight of fat}}{\text{weight of sample}}\right) \times 100 \qquad (6)$$

g. Percentage carbohydrate content

The method used for the determination of the percentage carbohydrate content was essentially the difference method. In this method, the carbohydrate content was obtained by subtracting the sum of all the estimated other fractions from 100% using equation (7)

$$\text{Percentage carbohydrate} = 100 - (\%\ \text{moisture} + \%\ \text{ash} + \%\ \text{fat} + \%\ \text{protein} + \%\ \text{fibre}) \qquad (7)$$

Statistical analysis

All the data collected were analyzed using Analysis of Variance (*ANOVA*) with *SAS* (Statistical Analysis System version 8, 1999) software. The means were separated using the Least Significant Difference Test (*LSD*) at a 0.5 percent level of probability.

RESULTS AND DISCUSSION

The mean values of the percentage crude protein content before and after storage are presented in Table 1. There were significant differences ($P \leq 0.05$) between the samples before and after storage, and likewise between treated and untreated samples in terms of protein content. The level of crude protein before storage was 6.17%, and the samples treated with neem leaf powder were reduced by just 0.52% to record the highest crude protein content (5.65%), while the lowest content (5.57%) was observed on the control. This could be due to the effect of monoterpenes, antioxidants, and other phytochemicals present in the neem extract, which lowered the protein metabolism through enzymatic activity and respiration (Tirosele et al., 2015; Sanon et al., 2017; & Ileke et al., 2020). This result is in line with Ezzat et al. (2016), who reported that the biochemical constituents of plant extracts help reduce protein breakdown. The storage method had a highly significant effect ($P \leq 0.01$) on the crude protein content before and after storage. The potato tubers stored in the corrugated fiber carton gave the highest means (5.44%) despite losing 0.43% crude protein content after storage, while the floor (control) and the perforated polypropylene plastic bags both recorded the lowest mean values of 5.24% each, and all were lower than the value before storage by 0.93%.

Table 1: Effect of plant extracts and storage methods on the proximate composition of potato during storage

	Protein	Fat	Fibre	Nutrient Ash	% Moisture	D/matter	Carbohydrate
			Before	Storage			
Treatment	6.17	1.89	1.05	3.09	70.56	31.98	22.49
			After	Storage			
Plant Powder							
Neem	5.65	0.91	0.75	2.70	69.34	30.63	20.62
Ginger	5.60	0.92	0.74	2.69	69.34	30.60	20.52
Control	5.57	0.89	0.72	2.68	69.31	30.54	20.51
Prob. of F	0.05	0.03	0.05	0.05	0.02	0.03	0.0012
LSD	0.025	0.0154	0.008	0.0088	0.125	0.050	0.031
Storage Method							
Basket	5.45	0.96	0.69	2.78	68.86	30.45	19.48
Pit	5.74	0.82	0.78	2.81	69.83	29.73	20.44
Jute	5.60	0.92	0.70	2.53	68.93	31.13	21.62
Carton	5.44	1.03	0.72	2.69	69.49	31.13	21.39
Polypropylene	5.24	1.03	0.70	2.53	68.86	31.05	21.39
Floor (Control)	5.24	0.69	0.69	2.07	68.24	31.72	18.69
Prob. of F	0.05	0.03	0.01	0.03	0.05	0.04	0.05
LSD	0.001	0.0001	0.001	0.001	0.001	0.001	0.0001
PP×SM	NS	NS	NS	NS	NS	NS	NS

Key: PE = Plant Extract: SM = Storage Method

This could be attributed to the modified atmosphere created inside the pit by the respiration of the tubers, which reduced the quantity of oxygen in the pit. The findings of this study are comparable to those of Dandago & Gungula (2011); Ezeocha & Ironkwe (2017); Ahmed (2023), who stated that the pit storage helps preserve protein content through reduced respiration caused by the modified atmosphere created inside the pit.

The plant extracts had a significant ($P \geq 0.05$) effect on the crude fat content after two weeks of storage, even though there was a 0.97% decrease in the fat content when compared to the baseline value as shown in Table 1. The highest crude fat content was reported on tubers treated with neem (0.92%) and ginger powder (0.91%), which were both statistically similar, whereas the lowest crude fat content was recorded on the untreated sample, i.e., the control sample (0.89%). This result could be attributable to the effect of the phytochemicals present in the plant extracts on minimizing the enzymatic activities of potato tubers during storage. This finding is in agreement with Ezzat et al. (2016), who posited that plant extracts contain phytochemicals that help preserve potato nutrients by lowering their biochemical and enzymatic activities.

In the case of storage method, there were highly significant differences ($P \leq 0.01$) among the different storage methods on the percentage crude fat content, but the highest value of 1.03% each was recorded on fiberboard cartons with sawdust and perforated polypropylene plastic bags, which declined by 0.86% (Table 1). The tubers stored on the floor (control) had the lowest value of 0.69%, which could be due to the restricted airflow in the two storage methods that lowered the rate of respiration. The findings of this study are in agreement with Haider et al. (2022); Ahmed (2023), who stated that storage methods affected the nutritional composition of ordinary and sweet potatoes respectively.

The percentage crude fiber content of potatoes treated with neem and ginger plant extracts was significantly different ($P \geq 0.05$) from other treatments, as were the values before and after two weeks of storage, as shown in Table 1. The highest crude fiber content was observed on the tubers treated with neem leaf (0.75%) and ginger (0.74%) powder, even though it was lower than the value before storage by 0.35%. However, the lowest fiber content was reported on untreated tubers, which could be attributed to the influence of plant extracts on the depressing biochemical process of the tubers, as reported earlier by Ezzat et al. (2016). Storage methods, however, showed a highly significant ($P \leq 0.01$) effect on the crude fiber content; the highest mean value of 0.78% was recorded in pit storage; nonetheless, it was diminished by 0.27% after storage (Table 1). The lowest mean value of 0.69% each was recorded on both basket and floor storage, which may be attributable to the modified atmosphere created within the pit, which reduced the rate of respiration of the tubers. The result of this research is consistent with Dandago & Gungula (2011), Sugri et al. (2017), Jiru & Usmane (2021); Ahmed (2023), who reported that pit storage promoted nutrient preservation in sweet, Livingstone, and ordinary potatoes, respectively.

Treating potato tubers with plant extracts had a significant ($P \geq 0.05$) effect on their percentage ash content after storage for two weeks (Table 1). The tubers treated with neem leaf powder recorded the highest ash content of 2.70%, which is lower by 0.39% than the baseline value of 3.09%, while the lowest value of 2.68% occurred on tubers treated with no plant extract. The chemical composition of the neem leaf extract may be responsible for lowering the rate of enzymatic biochemical processes in the tuber. This is consistent with Ezzat et al. (2016), who observed that monoterpenes and antioxidants are present in plant extracts, which reduce the enzymatic biochemical process of potato tubers. There was a significant difference ($P \geq 0.05$) between the ash content of potato tubers before and after storage; similarly, those subjected to different storage methods are shown in Table 1. Those stored in the pit had the highest ash content (2.81%), even though it was less than the initial value before storage (3.09%) by 0.28 percent. On the other hand, the lowest percentage ash content (2.07%) was recorded on the floor storage method. This could be due to the reduced respiration rate associated with a modified atmosphere, which is characterized by a lower oxygen level in the pit, which assists in conserving nutrients such as the ash content. The outcome of this study is similar to that of Dandago & Gungula (2011); Ahmed (2023) who reported that pit storage affected the nutrient content of sweet and ordinary potato tubers respectively.

The percentage moisture content of potatoes after two weeks of storage showed a significant ($P \geq 0.05$) difference in the moisture content before and after storage equally between the treatments with different plant extracts, as presented in Table 1. The fresh tubers (70.56%) varied with the stored ones (69.34%) with a content of 1.22%. The influence of the storage method on the percentage moisture content was also significant ($P \leq 0.05$), as shown in Table 1. The highest value was recorded on pit storage with a value of 69.83%, while the lowest content was recorded on floor storage with a value of 68.24%. The moisture content of tubers stored in the pit was reduced by only 0.73% after two weeks of storage, which could be attributed to the modified atmosphere created in the pit, which reduced moisture loss. This finding is in line with Dandago & Gungula (2011), Sugri et al. (2017), Ezeocha & Ironkwe (2017); Ahmed (2023), who reported that pit storage helps to minimize moisture loss during storage through reduced respiration and evaporation rates.

The percentage of dry matter content after two weeks of potato storage was significantly ($P \geq 0.05$) affected by storage and treatments with different plant extracts, as presented in Table 1. The highest content of dry matter was recorded on tubers treated with neem leaf powder (30.63%), but the lowest dry matter content was presented by tubers treated with no plant extract (30.54%). The variation in dry matter content before and after storage was 1.35%, which could be due to the influence of phytochemicals present in neem leaf extract on the physiological processes of the tubers during storage, such as respiration, which affected the dry matter content. This result is in agreement with Ezzat et al. (2016), who discovered that the chemical constituents of plant extract can affect the biochemical processes of potato tubers. Concerning the storage method, dry matter content was significantly ($P \leq 0.05$) influenced by the storage method (Table 1). The potato tubers stored on the floor recorded the highest dry matter contents (31.72%); nevertheless, it was less than the initial value by 0.26%, while the lowest value (29.73%) was recorded on tubers stored in the pit. This may be due to the high moisture loss associated with the bare floor storage method, which exposes the samples to harsh environmental conditions that enhance the evaporation rate. The outcome of this research is similar to Agbemafle et al. (2014); Haider et al. (2022), who reported that storage methods influence the nutritional composition of ordinary and sweet potatoes.

The mean percent carbohydrate content before and after storage was significantly high ($P \leq 0.001$), as was the mean percent carbohydrate content among the samples treated with plant extracts (Table 1). The highest mean value of the carbohydrate contents of potato tubers before storage was 22.49%, and after storage, the tubers treated with neem leaf powder recorded the highest mean value of 20.62% with a difference of 1.87%. The result between ginger treatment (20.52%) and control (20.51%) were both statistically similar. This outcome could be attributed to the effect of the phytochemical component of neem leaf powder on the physiological processes of potato tubers, which lowered the rate of respiration and consequently conserved the carbohydrate content, which is the main substrate of respiration (Dandago & Gungula, 2011; Ezeocha & Ironkwe, 2017; Jiru & Usmane, 2021; Ahmed, 2023). This result is the same as that of Ezzat et al. (2016), who observed that the chemical constituents of neem leaf powder preserve the nutrient content. With respect to the storage methods, the mean value for the carbohydrate content of potatoes before and after storage showed a significant ($P \leq 0.05$) difference among the samples stored under different storage methods (Table 1). The highest mean carbohydrate content (21.62%) was recorded on tubers stored in the jute storage, even though it was less than the percentage carbohydrate content before storage (22.49%).

On the other hand, the lowest carbohydrate value of 18.69% was recorded on the floor storage method. This outcome could be due to the modified atmosphere created in the pit, which helps preserve the carbohydrate content by slowing down respiration rates due to the low level of oxygen and the high level of carbon dioxide inside the pit. This outcome is in agreement with Dandago & Gungula (2011), Agbemafle et al. (2014), Ezeocha & Ironkwe (2017), Ahmed (2023), who reported that pit storage helps preserve the nutrient content of sweet, Livingstone, and ordinary potatoes, respectively by modifying the gas composition of the pit.

CONCLUSION

As a result of the research conducted, it was found that the neem leaf powder and pit storage methods showed very good results in reducing the nutrient content depletion during storage. The obtained data also indicated that the studied plant powder (neem leaf powder) and the storage method (pit storage) could be used as an alternative to the expensive storage methods unaffordable by our farmers in developing countries. Therefore, its adoption is recommended to minimize the postharvest losses of potato tubers of smallholder and organic farmers.

REFERENCES

Adebayo, A. A., and Zemba, A. A. (2020). Climate. In: Adebayo, A.A.; Tukur, A.L.; and Zemba, A.A. (Eds). *Adamawa State in Maps*. Second Edition. Paraclete Publisher, Yola. 31-36.

Ahmed, M. (2022). Effect of curing period, plant hormones, and on-farm storage methods on the physiological losses of potato (*Solanum tuberosum* L.) tubers. *New Countryside*. 01(02), 23-36. https://doi.org/1055121/nc.v1i2.41

Ahmed, M. (2023). Effect of the curing period, ABA rates, and storage methods on the storability of potato (*Solanum tuberosum* L.) tubers in Mubi, Adamawa State, Nigeria. Ph.D. Thesis, Modibbo Adama University, Yola, Nigeria.

Ahmed, M., and Gungula, D. T. & Tame, V. T. (2022). Effects of curing time, abscisic acid, and storage methods on the organoleptic properties of boiled potato (*Solanum tuberosum* L.) chips. *Journal of Agricultural and Value Addition*, 5(2), 54–81. https://dx.doi.org.104038/java.v5i2.48

Ahmed, M., Gungula, D. T. & Tame, V. T. (2023). Effects of postharvest management on the microbial quality of potato (*Solanum tuberosum* L.) tubers. *Acta Universitatis Sapientiae, Alimentaria*. 16,1-17. https://doi.org.102478/ausal-2023-0001

Agbemafle, R., Sekyere, J. D. O., Otchere, J. K. Acquaye, A., Diabor, E. & Asi, J. (2014). Effect of Different Storage Methods on the Proximate Composition and Functional Properties of Cream-Skinned Potato (*Ipomoea batatas* Lam). *Scholars Journal of Engineering and Technology*, 2(1), 33–44.

AOAC (2020). Association of Official Analytical Chemists. Official methods of analysis, 19th edition. Washington, DC, USA.

Awojobi, B.F. 2004. Indigenous knowledge in potato utilization, processing, and preservation. In Olakesusi, F. (Eds). Proceedings of Postharvest seminar P.1-127.Ilorin: Nigerian Stored Products Research Institute.

Ayalew, T.; Struik, C.P. & Hirpa, A. (2014). Characterization of seed potato (*Solunum tuberosum* L.) storage, pre-planting treatment, and marketing systems in Ethopia: The case of the West-Arsi zone. *African Journal of Agricultural Research*, 9(15),1218–1226. https://doi.10.5897/AJAR2013.8572

Bembem, K. & Sadana, B. (2013). Effect of cooking methods on the nutritional composition and antioxidant activity of potato tubers. *International Journal of Food and Nutritional Science*, 2(4), 26–30.

Burgos, G., Felde, Z.T., and André, C. & Kubow, S. (2020). The potato and its contribution to human diet and health. In: Hugo Campos and Oscar Ortiz (Eds. The potato crop: its agricultural, nutritional, and social contribution to humankind. Springer Nature Switzerland AG. https://doi.org/10.1007/798-3-030-28683-5_3

Dandago, M .A., & Gungula, D. T. (2011). Effects of various storage methods on the quality and nutritional composition of sweet potato (Ipomea batatas L.) in Yola, Nigeria. *International Food Research Journal*, 18, 271-278.

Devaux, A., Goffart, J., Petsakos, A., Kromann, P., Gatto, M., Okello, J., Suarez, V., & Hareau, G. (2020). Global food security, contributions from sustainable potato agri-food systems In Hugo Campos and Oscar Ortiz (Eds). *The potato crop: its agricultural, nutritional, and social contribution to humankind*. Springer Nature Switzerland AG. https://doi.org/10.1007/978-3-030-28683-5_1

Ezeocha, C. V., & Ironkwe, A. G. (2017). The effect of storage methods and period on the physiological and nutritional components of the Livingstone potato (*Plectranthus esculentus*) in Abia State, Nigeria. *De Gruyter Open Agriculture* (2), 002213–219. https://doi.10.1515/opag

Ezzat, A. S., El-Awady, A. A., & Tawfik, A. A. (2016). Using some plant extract to control mechanical injuries, pest management increases the productivity and storability of potatoes (*Solanum tuberosum* L). *Journal of Plant Production, Mansoura University Horticultural Research*. 7(8), 801–811.

FAO. (2022). Agricultural production statistics. 2000–2021. FAOSTAT Analytical Brief Series No. 60. Rome. https://doi.org/10.4060/cc3751en

Haider, M.W., Nafees, M., Ahmad, I., Ali, B., Maryam, A., Iqbal, R., Vodnar, D.C., Marc, R.A., Kamran, M., Saleem, M.H., Al-Ghamdi, A.A., and Al-Hemaid, F.M. & Elshikh, M.S. (2022) Postharvest dormancy-related changes of endogenous hormones in relation to different dormancy-breaking methods of potato (Solanum tuberosum L.) tubers. *Frontier of Plant Science*. 13, 945256. https://doi.10.3389/fpls.2022.945256

Jiru, T.U., & Usmane, I. A. (2021). Effect of curing methods on the shelf life of fresh potato storage in the east Hararghe zone of the Oromia region. *Food Science and Nutrition Therapy*. 7(1), 011-017. https://doi.10.17352/jfsnt.000027.

Ijah, U. J .J, Auta, H. S,, Aduloju, M. O. and Aransiola, S. A. (2014). Microbiological, nutritional of bread produced from wheat and potato flour blends. *International Journal of Food Science*. (2014), 1-6. https://doi.10.1155/2014/671701 .

Ileke, K. D., Idoko, J. E. Ojo, D. & O. Adesina, B, C. (2020). Evaluation of botanical powders and extracts from Nigerian plants as protection of maize grains against maize weevil, *Sitophilus zeamais* (Motschuulsky) [Coleoptera: Curcculionidae]. *Biocatalysis and Agricultural Biotechnology*. 27. https://doi.10.1016/1179543318790260

Okonkwo, J. C., Nwokocha, H. N., & Ifenkwe, O. P. (1988). Effect of storage environment on post-harvest losses and subsequent field performance of some potato (*Solanum tuberosum*) cultivars. *Nigeria Agricultural Journal*, 23, 41-56.

Sanon, A., Zakaria, I., Clementine, D., & Honora, R.C. (2017). Potential of botanicals to control Callosobruchus maculatus (Col: Chrysomelidae, Bruchinae), a major pest of stored cowpeas in Burkina Faso: A review. *Sage*, 10,1–8. http//:doi.10.1177/j.bcab.2020.101702

Sugri, I., Maalekuu, B. K., and Kusi, F., & Gaveh, E. (2017). The quality and shelf-life of sweet potatoes are influenced by storage and postharvest treatments. *Trends in Horticultural Research*, 7,10–10.

Tiroesele, B., Thomas, K., & Seketeme, S. (2015).Control of cowpea weevil, *Callosobruchus maculatus* (F.) (Coleoptera: Bruchidae), using natural plant products. *Insects*, 6,77-84. https//:doi:10.3390/insects6010077

Tolessa, E. S. (2018). Importance, nutrient content, and factors affecting the nutrient content of potatoes. *American Journal of Food, Nutrition, and Health*, 3(3), 37–41.

Ugonna, C. U., Jolaoso, M. O., & Onwualu A. P (2013). A technical appraisal of potato value chain in Nigeria. *International Research Journal of Agricultural Science and Soil Science* 3(8), 291-301. http:/dx.doi.org/10.14303/irjas.2013.084

Wichrowska, D. (2022).Antioxidant capacity and nutritional value of potato tubers (*Solanum tuberosum* L.) as a dependence of growing conditions and long-term storage. *Agriculture* 2022, *12*(1), 21; https://doi.org/10.3390/agriculture12010021

Zaman, S., Hssani, D., Khalid, M., Erum, S., Shah, S. H. & Che, S. (2014). Assessment of fifteen selected potato (*Solanum tuberosum* L.) genotypes on the basis of biochemical characteristics. *International Journal of Biology, Pharmacy, and Allied Sciences*, 5(3),725-735.