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Full Length Research Paper

The Effect of Processing on the Antioxidant Activities of Purple Onions (*Allium Cepa L.*), Bulb.

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Abstract

Onion (*Allium cepa* L.*)* is a common vegetable and is widely consumed all over the world. It has been used as a food and medicinal crop since ancient times; it is grown worldwide and because of its peculiar taste, unique flavor, highly valued aroma, and various health benefits, it is sometimes referred to as the "Queen of the kitchen". Onions is traditionally used as fresh condiment, but recently, particularly in the year 2020, the scarcity of the commodity has led to a thought of processing and preserving it for the scarcity period. The present study was therefore, conducted to evaluate the effect of processing on the antioxidant activities of fresh, sun dried and oven dried purple onion bulb. Two processing methods which included sun-drying and oven-drying at 70^{o}C were used. The antioxidant activities were determined using standard biochemical methods. The oven dried sample showed better antioxidant activities when compared to the other samples. The results of the parameters analyzed in this study, suggests that oven drying (70^{o}C) is the most efficient method of processing and preservation of purple onion, since it gave the best results among the samples assessed. Therefore, it can be concluded that oven dried purple onions have enhanced antioxidant properties making it a good candidate for the prevention and therapy of array of diseases which meets consumer requirement of being readily available all seasons.

Keywords: Onions, Prevention, Processing, Therapy, Antioxidant, Lipid peroxidation

Introduction

Onion (*Allium cepa L.*, from Latin *cepa* meaning "onion") is a common vegetable and is widely consumed all over the world (Zhang *et al*., 2016; Pareek *et al.,* 2017). It was originated in central Asia and is one of the oldest cultivated plants, with cultivation records dating back more than 4000 years. It has been used as a food and medicinal crop since ancient times; it is grown worldwide in 170 countries (Petropoulos *et al*., 2017). Because of its peculiar taste, unique flavor,

highly valued aroma, and various health benefits, it is sometimes referred to as the "Queen of the kitchen" (Griffiths *et al.,* 2002). It belongs to the family of Alliaceae and is one of the oldest commonly used vegetables known to mankind around the globe. In the early 1970s, it was the most widely cultivated species of the genus *Allium* (Eric, 2010). There are three types of onion based on color, that is, purple or red, yellow and white, and all have different flavors and pungency from mild to highly strong according to color (Khandagale and Gawande, 2019).

According to numerous animal research and clinical studies, onion has been used for the treatment/ management of various ailments such as asthmas, cancer, diabetes, hypocholestremic, and osteoporosis (Marrelli *et al.,* 2019). Indeed, quercetin is thought to be involved in all these health benefits due to its strong antioxidant activity. Regular consumption of onions has been reported to reduce the risk of cancer, cataract, DNA damage, vascular and heart diseases (Arung *et al.,* 2011). The color of purple onions is primarily due to anthocyanins present in the epidermal cells of the scale leaves of the bulb, and their main anthocyanin pigment is reported to be cyanidin 3-glucoside (Lee *et al.,* 2015). Regarding flavor or pungency, the sulfur compounds "allyl propyl disulfides" are responsible for the peculiar smell of onion. The sweet taste in cooked onions is due to the reaction of heat on Sulphur compound and the flavours come from sulphur compound activated by the enzyme allinase. Onion contains thio-pronanal oxide which produces a weak sulphurous acid that cause pains in the eyes, thus producing tears (Ihekoronye and Ngoddy, 1985). It has been observed that during processing, ketones are released by the Maillard reaction that is responsible for the aroma of onion (Liu *et al.,* 2020). The onion bulb and skin contain various bioactive compounds, such as organosulfur compounds (OSCs), thiosulfinates, polyphenols, including flavonoids, fructooligosaccharides (FOS) and vitamin C (Putnik *et al.,* 2019) and among them, flavonoids are the most effective bioactive compounds. Two principal subgroups of flavonoids are anthocyanins, quercetin, and quercetin derivatives, which impart different colors to onion skins from yellow to purple (Benítez *et al.,* 2011). Quercetin aglycone, quercetin diglucoside, quercetin 4′-glucoside, and kaempferol are the primary flavonoids of onion (Sagar *et al.,* 2020). Waste onion skin also contains a higher level of flavonoids than the edible part (Duan *et al.,* 2015) due to the oxidation of quercetin flavonol into 3,4-hydroxybenzoic acid and 2,4,6-trihydroxyphenylglycosilic acid and concentrated in dried onion skin to protect the bulb from soil microbes (Takahama and Hirota, 2000).

Even though *Allium cepa L.* is widely used as a food and medicinal crop since ancient times, knowledge on the effect of processing on the antioxidant properties is lacking. This study, therefore, will provide critical information on onion antioxidant properties after its transformation from fresh to dry. It will also help to make an appropriate choice of the method of processing that will produce health promoting onion powder meeting modern consumer requirements.

Plate 1: Fresh purple onion bulb for fresh sample (Photo by Ijeoma, 2022)

Plate 2: Fresh sliced purple onions for Sun drying sample (Photo by Ijeoma, 2022)

Plate 3: Fresh sliced purple onions for oven drying sample at 70ºC (Photo by Ijeoma, 2022)

Materials and Methods

Sample collection and identification

The *Allium cepa L.* (purple onion bulb) was purchased from Ose Market, Onitsha North Local Government Area, Anambra State. The primary source of the onions according to the sellers was from Aliero, a town in Kebbi State of Nigeria. The samples were randomly selected based on their freshness and bulbs were checked for any physical

defect and were transported in polyethylene bags to Botany Department, Nnamdi Azikiwe University, Awka, Anambra State, Nigeria. The samples were identified and authenticated by a taxonomist, and a voucher specimen was deposited and a voucher number of NAUH-25^{A} was issued to the specimen at Herbarium Unit.

Sample preparation

The epicarps of the purple onion bulb were removed and separated from the stalks for easy assessment. About 500g of raw purple onion bulbs for fresh sample were stored in a cool, dry, well-ventilated place until sun dried, and oven dried samples were ready for analyses. About 500g of samples for oven drying were sliced into chips and dried in an electric oven at a temperature of 70^{o}C for 48hours. Also, about 500g of samples for sun drying were sliced into chips and dried under the sun from 8:00am – 6:00pm daily for 21days in March and packed in polyethylene bags to avoid accumulation of moisture. After drying, the chips were ground/pulverized into fine powder using Electric blender. The powdered samples were stored in an airtight bottle at room temperature (between 25-30^{o}C); then both are ready for use for analyses. Then the bulb onion sample for fresh was sliced and pulverized into fine paste using Electric blender. The paste sample was stored in an airtight bottle for analyses.

Extraction procedure

After, each sample were mixed with about 1000ml of ethanol in a bowl followed by vigorous shaken for 5minutes and tightly covered with foil paper and stored for 72 hours. After 72 hours, it was filtered using whatman filter paper and funnel. The filtrates were evaporated to dryness by using a water bath at the temperature of 40˚C for few days and the ethanolic extracts gotten were stored in an airtight container for future use.

***In vitro* Antioxidant assay**

Free radical scavenging activity Assay.

The stable 2,2-diphenyl-1-picryl hydrazyl radical (DPPH) was used for the determination of free radical scavenging activity of the ethanolic extract of the samples. This was done using the method of Ebrahimzadem *et al.*, (2009).

Briefly, an aliquote (0.3ml) of different concentrations of the extract (0-1000µg/ml) were mixed with 2.7ml of methanolic solution of DPPH (100µm) in test tubes. The mixture was shaken vigorously and kept in a dark at room temperature for 60minutes. The absorbance was taken at a wavelength of 517nm using spectrophotometer. Butylated Hydroxyanisole (BHA) was used as standard. The percentage scavenging activity was calculated using the formular:

$$\%RSA = [(A_{DPPH} - A_S) / A_{DPPH}] \times 100$$

Where A is the absorbance of the test solution with the sample and A_{DPPH} is the absorbance of DPPH solution. The EC_{50} (concentration of sample at 50% RSA) was calculated from the graph of % RSA against the sample concentration.

Inhibition of Lipid peroxidation Activity assay

Determination of the extent of inhibition of lipid peroxidation was carried out using the method of Barros *et al.,* (2007). A goat head was purchased from Kwata Slaughter at Awka from a goat of approximately 70kg. The brain was dissected and homogenized with pestle and mortar in an ice cold Tris-HCl buffer (pH 7.4, 20mM) to produce 50% w/v brain homogenate which was centrifuged at 3000rpm for 10mins. An aliquot (0.1ml) of the supernatant was incubated with 0.2ml of the sample extract at various concentrations (0-10µg/ml), in the presence of 0.1ml of 10µM ferrosulphate and 0.1ml of 0.1nM ascorbic acid at 37^{o}C for 1hr. The reaction was stopped by the addition of 0.5ml of 28% TCA

(Trichloroacetic acid) followed by the addition of 0.38ml of 2% TBA (Thiobarbituric acid). The mixture was then heated at 80^{o}C for 20minutes. After centrifugation at 3000rpm for 10minutes to remove the precipited protein, the colour intensity of the malondialdehyde (MDA)-TBA complex in the supernatant was measured by its absorbance at 532nM. The inhibition ratio (%) was calculated using the following formular:

Inhibition ratio (%) = [(A-B)/A] ×100%.
Where A and B were the absorbance of the control and the compound solution respectively. The extract concentration providing 50% lipid peroxidation inhibition (IC_{50}) was calculated from the graph of antioxidant activity percentage against the extract concentrations. BHA was used as the standard.

Reducing power capacity assay
The reducing power capacity of the extracts was determined using the method of Barros *et al*., (2007). This method is based on the principle of increase in the absorbance of the reaction mixture of substances, which have reduction potential, react with potassium ferricyanide (Fe^{3+}) to form potassium ferrocyanide (Fe^{2+}), which then reacts with ferric chloride to form ferric–ferrous complex that has an absorption maximum at 700 nm. Briefly, an aliquot 2.5ml of various concentration of ethanolic extract of the samples (0-10µg/ml) was mixed with 2.5ml of 0.2M sodium phosphate buffer (pH 6.6) and 2.5ml of 1% potassium ferricyanide. The mixture was incubated at 50^{o}C for 20minutes. Then, 2.5ml of 10% Trichloroacetic acid was added, and the mixture centrifuged at 1000rpm for 8minutes. The upper layer (5ml) was mixed with 5ml of deionised water followed by the addition of 1ml of 0.1% ferric chloride. The absorbance was measured at 700nm. The graph of absorbance at 700nm against the extract concentrations was plotted. Butylated Hydroxyanisole (BHA) was used as a standard antioxidant.

Statistical analyses
All the samples and readings were prepared and measured in triplicate. The results were presented in mean ± standard deviation. The $p<0.05$ at 95% confidence level was selected as the level of significance. As for the data and graphs, they were subjected to analyses using Microsoft Office Excel 2007 worksheet.

Results and Discussion
Percentage Radical Scavenging Activity of Fresh, Sun dried, Oven dried purple onion:
Result of percentage radical scavenging activities of Fresh, Sun dried, Oven dried purple onion and standard (BHA) as shown in fig. 1 below. The results revealed that oven dried sample is rich in antioxidant properties when compared to sun dried and fresh sample.

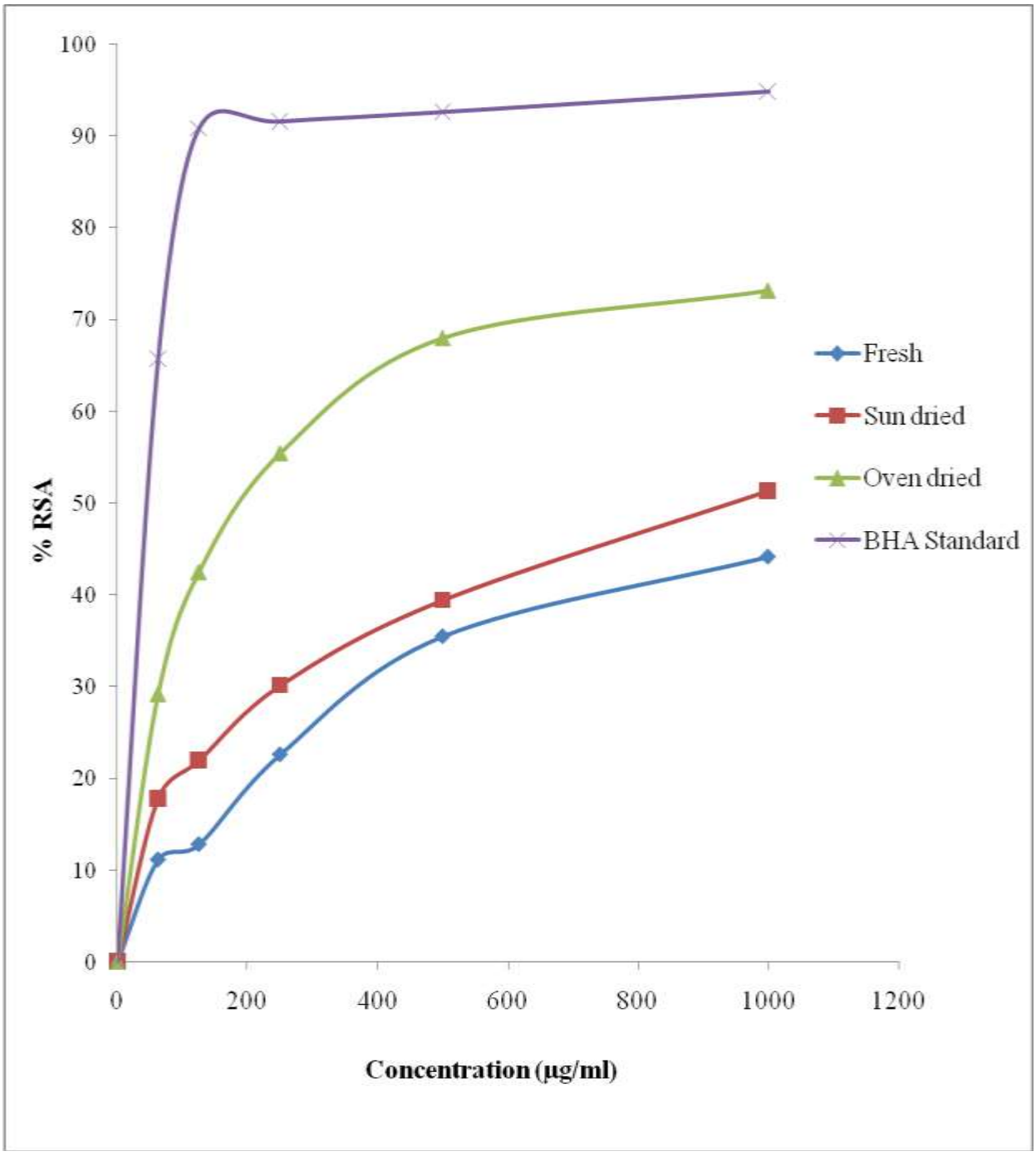

Fig. 1: Line graph Comparison of the percentage free radical scavenging activity of Fresh, Sun dried, Oven dried purple onion bulb (*Allium cepa L.*) and standard (BHA).

Inhibition of Lipid peroxidation Activity of Fresh, Sun dried, Oven dried purple onion:

Result of percentage inhibition of lipid perioxidation of Fresh, Sun dried, Oven dried purple onion and standard (BHA) as shown in fig. 2 below. The results revealed that oven dried sample reduced lipid peroxidation more than the sun dried and fresh samples.

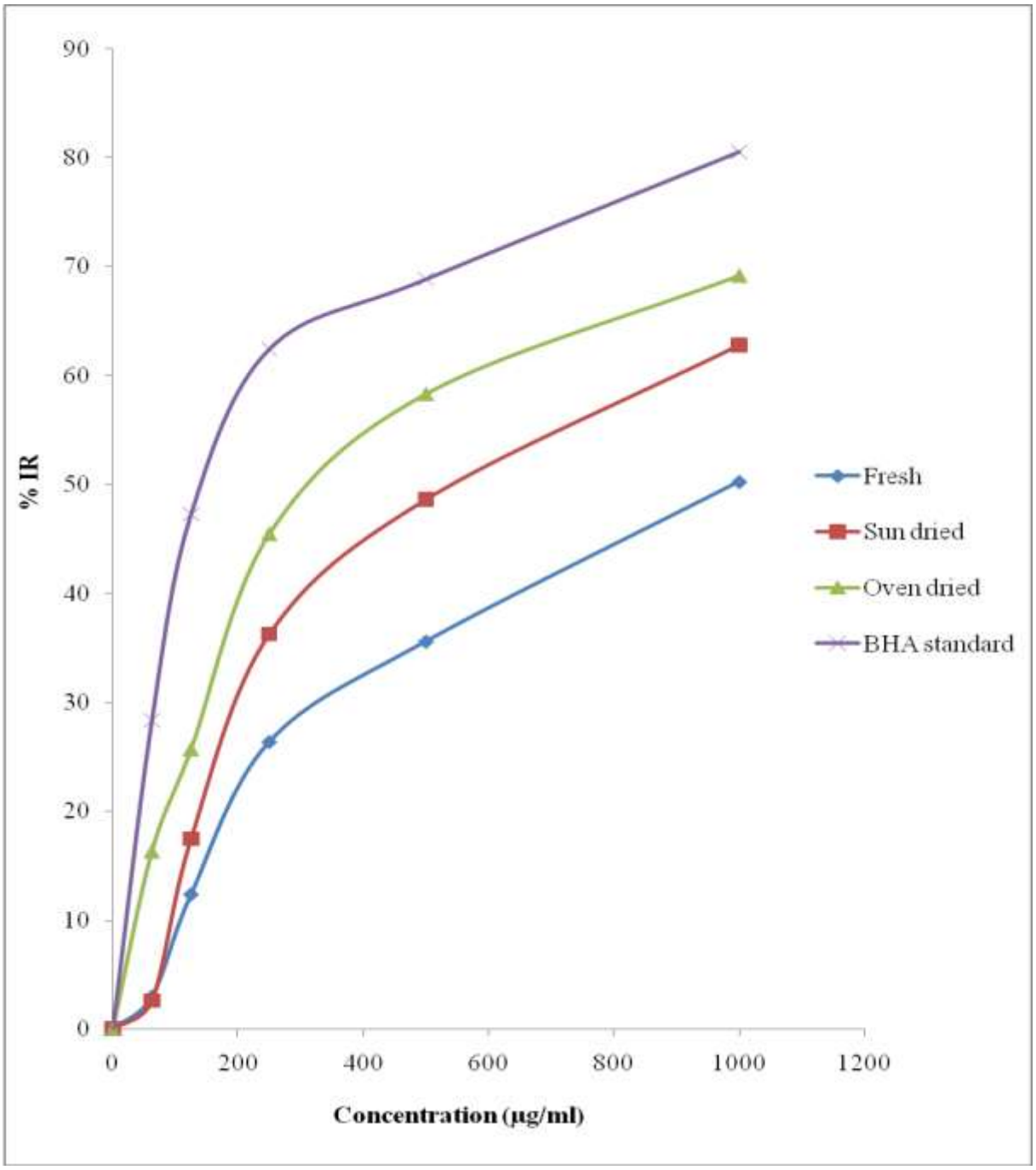

Fig. 2: Line graph for percentage Inhibition of lipid peroxidation of Fresh, Sun dried, Oven dried purple onion bulb (*Allium cepa L.*) and standard (BHA).

Reducing Power Capacity of Fresh, Sun dried, Oven dried purple onion:

Result of reducing power capacity of Fresh, Sun dried, Oven dried purple onion and standard (BHA) as shown in fig. 3 below. The results revealed that oven dried sample has a higher reducing power capacity when compared to sun dried and fresh sample.

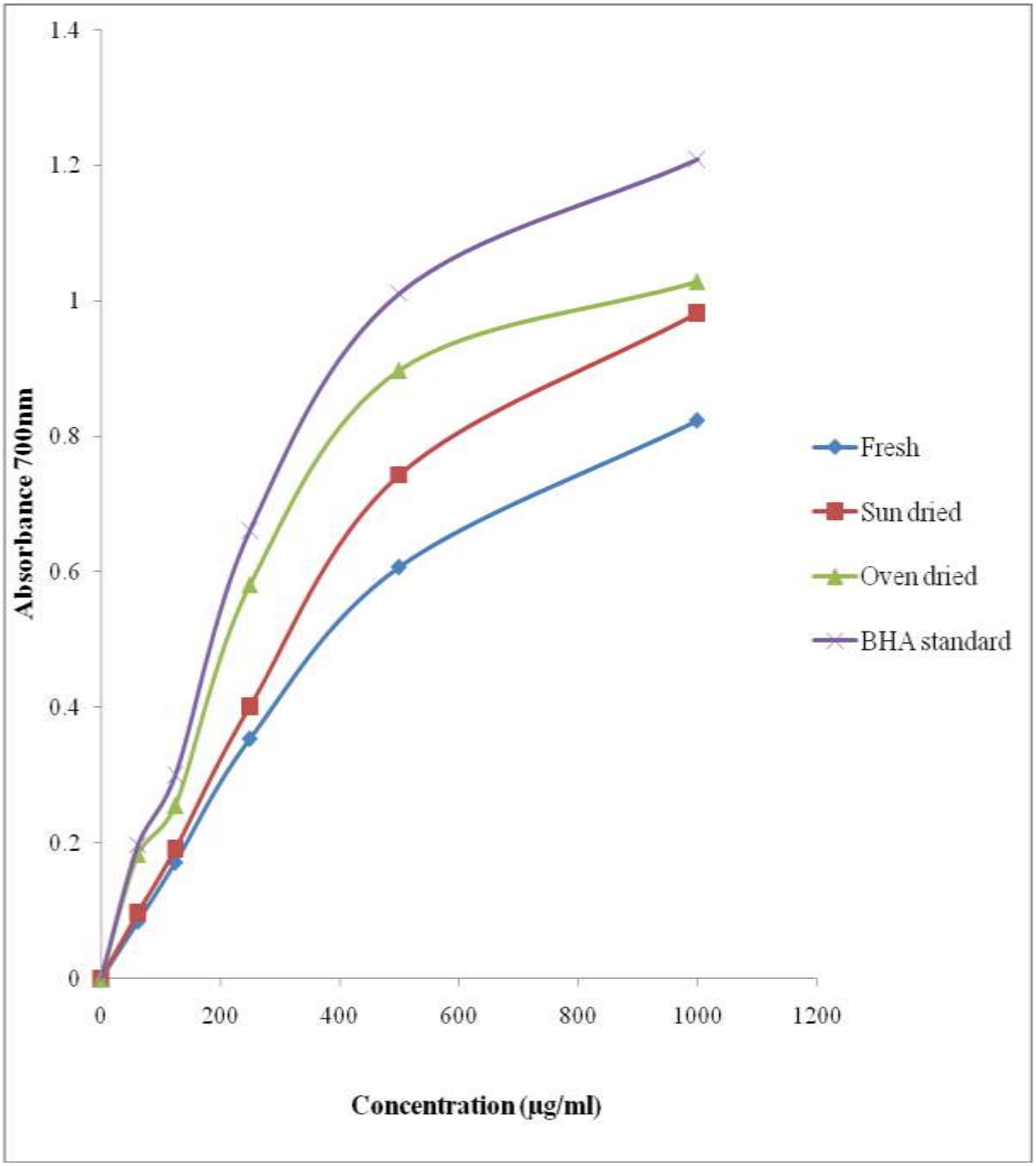

Fig. 3: Line graph dose response of the Absorbance vs samples concentrations of reducing power capacity of Fresh, Sun dried, Oven dried purple onion bulb (*Allium cepa L.*) and standard (BHA).

The EC_{50}, IC_{50} and $OD_{0.5}$ of the *In vitro* antioxidant activity of Fresh, Sun dried, Oven dried purple onion and standard (BHA):

Result of EC_{50}, IC_{50} and $OD_{0.5}$ of the *In vitro* antioxidant activity of Fresh, Sun dried, Oven dried purple onion and standard (BHA) as shown in fig. 4 below. The results were determined from the graphs plotted in Microsoft excel and calculated using the following steps:

1. Click one of the lines plotted.

2. Right click on it
3. Click add trend line.
4. Click display equation on chart.
5. Equation appears.
6. Substitute 50 as y-value for EC_{50}, IC_{50} and 0.5 as y-value for $OD_{0.5}$ respectively and solve for x, using these relevant equations obtained from the graphs in Microsoft excel as shown below:

Linear regression equations for %RSA values:

Fresh: $y = 0.041\times +7.723$; Sun dried: $y = 0.043\times +12.8$; Oven dried: $y = 0.058\times +25.71$

BHA: $y = 0.055\times +54.80$

Linear regression equations for %IR values:

Fresh: $y = 0.049\times +5.17$; Sun dried: $y = 0.062\times +7.673$; Oven dried: $y = 0.063\times +15.47$

BHA: $y = 0.064\times +27.13$

Linear regression equations for OD values:

Fresh: $y = 0.000\times +0.073$; Sun dried: $y = 0.001\times +0.081$; Oven dried: $y = 0.001\times +0.164$

BHA: $y = 0.001\times +0.180$

Lower EC_{50}, IC_{50} and $OD_{0.5}$ value represents higher antioxidant activity (Braca *et al.*, 2002).

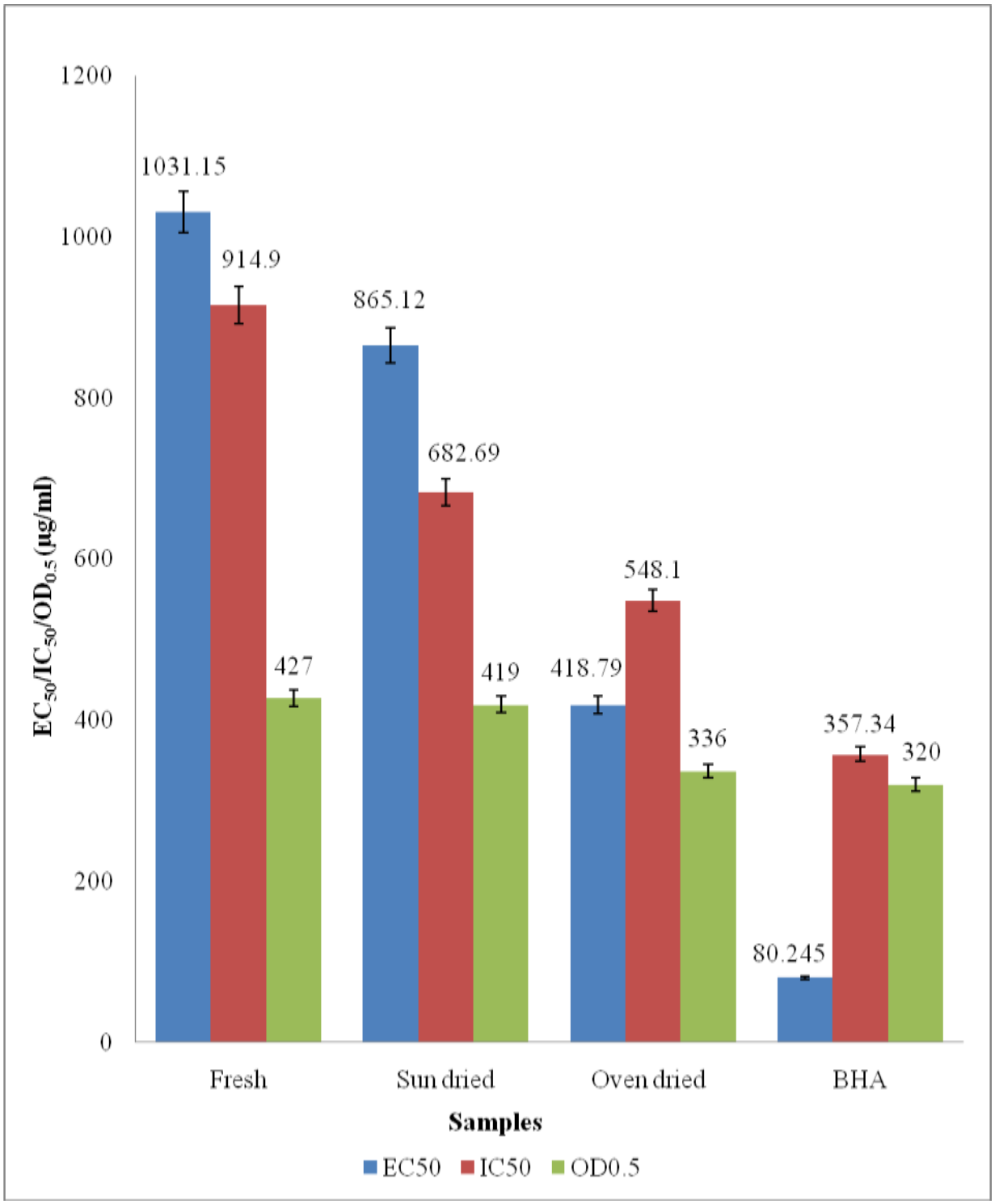

Fig. 4: The EC_{50}, IC_{50} and $OD_{0.5}$ of the *In vitro* antioxidant activity of Fresh, Sun dried, Oven dried purple onion and standard (BHA)

Discussion

From the results in figure 1 above, the percentage scavenging activities of fresh, sun dried and oven dried purple onion on DPPH radicals increased as the concentration increased in the range of 0 - 1000µg/ml and it was remarkable, especially in the case of oven dried sample. In terms of EC_{50} (i.e., the concentration of extract necessary to decrease the initial concentration of DPPH by 50% (EC) under the specified experimental condition), shows that percentage radical scavenging activities of fresh, sun dried and oven dried purple onion was lower than standard (BHA); indicating their weak free radical scavenging activities, but lowest value was shown by the positive control, BHA (80.245µg/ml), followed by oven dried (418.79µg/ml), sun dried (865.12µg/ml) and fresh purple onion (1031.15µg/ml) respectively. Previous researches showed that the radical scavenging activity was elevated at higher drying temperatures using oven drying method (Lee Mei Ling *et al.,* 2013; Rodriguzer *et al.*, 2014). It is believed that the high concentration of antioxidant in a dried sample might contribute to the high antioxidant activity. According to Animesh *et al.,* (2023), drying purple onion at temperature of 70^{o}C for 36hours were found to produce dried onion powder with the best balance of physical and antioxidant properties. The results clearly showed that oven dried purple onion sample has more capability to scavenge the free radicals when compared to sun dried and fresh purple onion, although the primary antioxidant activities of the three samples are lower than that of the standard (BHA). The results showed that the scavenging activities of the samples are in the following order: BHA>OD>SD>FRESH.

From the results in fig. 2 above, shows the percentage inhibition of lipid peroxidation activities of fresh, sun dried, and oven dried purple onion were lower than the standard (BHA), indicating their weak percentage inhibition of lipid peroxidation.

The process of lipid peroxidation has been suggested to proceed via a free radical chain reaction, which has been associated with cell damage in biomembranes. The damage has been shown to precipitate different diseases like cancer, cardiovascular diseases and diabetes.

In terms of IC_{50}, the lowest value is shown by the standard (BHA) (357.34µg/ml), followed by oven dried (548.10µg/ml), sun dried purple onion (682.69µg/ml) and fresh purple onion (914.90µg/ml). The results clearly showed that oven dried sample is more capable of slowing down or preventing the development of complications associated with diseases when compared to sun dried and fresh purple onions. The results showed that the percentage inhibition of lipid peroxidation of BHA and samples were in the following order: BHA>OD>SD>FRESH.

The lower EC_{50} value indicates the higher free radical scavenging ability of the oven dried sample, sun dried and fresh purple onions. So, oven drying as a processing method has a better antioxidant activity than sun dried, and fresh purple onions compared to butylated hydroxylanisole (BHA) which is a standard antioxidant at 418.79, 548.10 and 336 for EC_{50}, IC_{50} and $OD_{0.5}$ respectively (Animesh *et al.,* 2023). Sun dried sample was 865.12, 682.69 and 419 for EC_{50}, IC_{50}, and $OD_{0.5}$. The fresh sample had the least antioxidant activity, with 1031.15, 914.90 and 427 for EC_{50}, IC_{50}, and $OD_{0.5}$ respectively. Drying process especially drying temperature at 50, 70, and 90^{o}C for onion powder preparation, significantly affected the properties of the powders, especially at highest temperature (90^{o}C) had the strongest antioxidant activity (Dong-Jin *et al.,* 2016).

Also, Ahmad *et al.,* (2020) found that oven-dried purple and white onions showed higher amounts of phenolic content, flavonoid content and antioxidant activity than sun dried and fresh onions.

The reducing property of an antioxidant is based on the ability of the antioxidant fraction to reduce Fe^{+3} to Fe^{+2} represents the reductive power of the antioxidant (Ardestani and Yazdanparast 2007). From the results in fig. 3 above, reducing power of fresh, sun dried, and oven dried purple onions increases as the concentration increases at absorbance of 700nm. Also, according to Sahar *et al.,* (2016), in general, drying increases antioxidant activity, TPC, TFC and a decrease in vitamin C. Based on the results, oven dried sample has a higher reducing power capacity when compared to sun dried and fresh samples respectively. The results clearly showed that the reducing power of standard (BHA) and samples are in the following order: BHA>OD>SD>FRESH.

Conclusion

Based on the findings of the present study; the effect of processing on the antioxidant activities of fresh, sun dried and oven dried purple onion bulb using electrically powered oven at 70^{o}C. From the results and other relevant literatures showed that oven drying (70^{o}C) is mostly preferred to sun dried as a processing method because, it produces health promoting onion powder that is a rich source of antioxidant which possess both physiological as well as medicinal properties that can be beneficial in pharmacological basis for management and prevention of many diseases. Also, it contributes to the development of guidelines that produces onion powder that has optimal functional properties, and also help in reducing postharvest losses and improves the livelihoods of farmers. Furthermore, it is a way of transforming this all important condiment from fresh to dry powder that will meet modern consumers' requirements. This investigation might help to address the growing demand for good quality, antioxidants, and healthy dried onion powder among consumers and the food industry.

Recommendations

Several studies are currently ongoing on the production of onion powder. The present study reveals that the two processing methods employed in this research work such as sun dried, and oven dried all produce onion powder that promotes antioxidant properties. It is therefore very clear that this processing method (oven dried) produces onion powder that is capable of scavenging free radicals, higher reducing power capacity and more capable of slowing down or preventing the development of complications associated with diseases due to the high levels of antioxidant activities studied herein. It is, therefore recommended that further studies should be carried out in future, to ascertain the *in vivo* activities of the biological components found in this processed sample and also to determine the bioavailability of the nutrients therein.

References

Ahmad, S., Nurhan, U., Mehmet, A. O, (2020). The effect of oven drying on bioactive compounds, antioxidant activity and phenolic compounds of white and red-skinned onion slices. Journal of food processing and preservation, **45**(3).

Animesh, S., Md, W.H., Mahabub, A., Rahul, B., Mukta, R. and Md, I.H. (2023). Drying conditions and varietal impacts on physicochemical, antioxidant and functional properties of onion powder. *Journal of Agriculture and Food Research***, 12**(2): 100578**.**

Arung, E.T., Furuta, S., Ishikawa, H., Kusuma, I.W., Shimizu, K. and Kondo, R. (2011) Anti-melanogenesisproperties of quercetin- and its derivative-rich extract from *Allium cepa*. *Food Chemistry*. **124(**3): 1024–1028.

Ardestani, A., and Yazdanparast, R., (2007). Antioxidant and free radical scavenging potential of *Achilleasantolina* extracts. *Journa l Food Chemistry*, **104**:21–29.

Barros, L., Ferreira, M.J., Queiros, B., Ferreira, I. C. F. R. and Batista, P. (2007). Total phenols, ascorbic acid, á-carotene and lycopene in portuguese wild edible mushrooms and their antioxidant activities, *Food Chemistry*. **103**:1314 - 419.

Benítez, V., Mollá, E., Martin, A., Lopez, F., Downes, K., Terry, L. and Esteban, R. (2011). Study of bioactive compound content in different onion sections. *Plant Foods for Human Nutrition*, **66**(1): 48– 57.

Dong-Jin, L., Jung-Ah, H., and Seung-Taik, L. (2016). Enhancement of Antioxidant activity of onion powders by browning during drying process. *Korean journal food science technology*, **48**(1): 15-19.

Duan, Y., Jin, D.H., Kim, H.S., Seong, J.H., Lee, Y.G., Kim, D.S. and Jang, S.H. (2015). Analysis of total phenol, flavonoid content and antioxidant activity of various extraction solvents extracts from onion (*Allium cepa L.)* peels. *Journal of Korean Oil and Chemical Society*, **32**(3): 418– 426.

Ebrahimzadeh, M. A., Seyed, M. N., Seyed, F. N., Fatemeh B. and Ahmad, R. B. (2009). Antioxidant and free radical scavenging activity of *H. officinalis, L. angustifolius, V. odorata, B. hyrcana and C. speciosum. Pakistan. Journal of Pharmaceutical Sci*ence **23**(1): 29-34.

Eric, B. (2010). Garlic and other *Alliums*: The Lore and Science (Cambridge: Royal Society of Chemistry).

Griffiths, G., Trueman, L., Crowther, T., Thomas, B. and Smith, B. (2002). Onions—A global benefit to health. *Phytotherapy Research*, **16**(7): 603– 615.

Ihekoronye, A.I. and Ngoddy, P.O. (1985). Integrated Food Science and Technology for the Tropics. Macmillan Publishers Ltd. London and Oxford, Pp. 262-276. Irkin, R., and Korukluoglu, M. (2007). Control of *Aspergillus niger*with garlic, onion and leek extracts. *African Journal of Biotechnology*, **6**, 384–387.

Khandagale, K. and Gawande, S. (2019). Genetics of bulb colour variation and flavonoids in onion. The Journal of Horticultural Science and Biotechnology, **94**(4), 522–532.

Lee, E.J., Rezenom, Y.H., Russell, D.H., Patil, B.S. and Yoo, K.S. (2012). Elucidation of chemical structures of pink-red pigments responsible for 'pinking' in macerated onion (*Allium cepa* L.) using HPLC–DAD and tandem mass spectrometry. *Food Chemistry*, **131** (3): 852–861.

Liu, X., Xia, B., Hu, L.T., Ni, Z.J., Thakur, K. and Wei, Z.J. (2020). Maillard

conjugates and their potential in food and nutritional industries: A review. *Food Frontiers*, **1**(4): 382–397.

Marrelli, M., Amodeo, V., Statti, G. and Conforti, F. (2019). Biological properties and bioactive components of *Allium cepa* L.: Focus on potential benefits in the treatment of obesity and related comorbidities. *Molecules (Basel, Switzerland)*, **24**(1), 119.

Pareek, S., Sagar, N.A., Sharma, S. and Kumar, V. (2017). Onion (*Allium cepa Fruit L*) and Vegetable Phytochemicals: Chemistry and Human Health. 2nd ed. Hoboken, NJ: Wiley Blackwell. Pp. 1145-1162.

Petropoulos, S., Ntatsi, G. and Ferreira, I. (2017). Long-term storage of onion and the factors that affect its quality: A critical review. *Food Reviews International*, **33**(1): 62– 83.

Putnik, P., Gabrić, D., Roohinejad, S., Barba, F.J., Granato, D., Mallikarjunan, K. and Kovačević, D.B. (2019). An overview of organosulfur compounds from *Allium* spp.: From processing and preservation to evaluation of their bioavailability, antimicrobial, and anti-inflammatory properties. *Food Chemistry*, **276**: 680– 691.

Sagar, N.A., Pareek, S. and Gonzalez-Aguilar, G.A. (2020). Quantification of flavonoids, total phenols and antioxidant properties of onion skin: A comparative study of fifteen Indian cultivars. *Journal of Food Science and Technology*, **57**: 2423–2432.

Sahar, R., Mehdi, R., and Sayed, A. (2016). Evaluation of seven different drying treatments in respect to total flavonoid, phenolic, vitamin C content, chlorophyll, antioxidant activity and color of green tea (*Camellia sinensis* or *C. assamica*) leaves. *Journal of food science technology*, 53(1): 721–729.

Takahama, U. and Hirota, S. (2000). Deglucosidation of quercetin glucosides to the aglycone and formation of antifungal agents by peroxidase-dependent oxidation of quercetin on browing of onion scales. *Plant and Cell Physiology*, **41**(9): 1021– 1029.

Zhang, S.L., Deng, P., Xu, Y.C. and Wang, J. J. (2016). Quantification and analysis of anthocyanin and flavonoids compositions, and antioxidant activities in onions with three different colors. *Journal of Integrative Agriculture*, **15**(9): 2175–2181.