ISSN No:-2456-2165

Quality Assessment of Hurdle Preserved Onion Puree (HPOP) as a Convenience Product: A Preliminary Investigation

E.I. Oluwasola, A.L. Ahmad
School of Chemical Engineering,
Universiti Sains Malaysia
Nibong Tebal, Pulau Pinang, Malaysia

Adesina K., Okunade O.A, and Aiyegbusi O.O
Food Technology Department,
The Federal Polytechnic,
Ado - Ekiti, Ekiti State, Nigeria

Abstract: - Onion puree was formulated as a value-added product from two cultivars of onions (red and white). The hurdle preservative technique was employed to process and preserve the highly perishable vegetable. A comparative sensory and physiochemical evaluation was carried out on the Hurdle Preserved Onion Puree (Hpop) after thirty (30) days of storage at 4 ± 10 °C. The results obtained suggest that the Hpop produced was of acceptable quality and suitable for household, canteen, and other culinary uses as a convenience product. The sensory evaluation of the Hpop showed no significant difference in all the attributes evaluated (taste, aroma, color, and general acceptability) when compared to the fresh onion puree irrespective of the cultivar used. The vitamin C content of Hpopr1 and Hpopw1 with 10.09 mg/100g and 9.82 mg/100g respectively, is significantly higher than that of the fresh onion puree with 8.13 mg/100g and 7.20 mg/100g for the red and white cultivar, respectively. Therefore, the developed Hpop will not only improve the continuous accessibility and affordability of onion to different users of the product but can also stimulate the peasant farmers to profitably produce onion bulbs on a commercial scale without the usual fears of postharvest gluts.

***Keyword:** -Puree; Convenience; Preservation Onion; Hurdle*

I. INTRODUCTION

The name "onion" (Allium cepa L.) is derived from the Latin word 'unio,' which means 'single' or 'one' because the onion plant produces only a single bulb [1]. Onion has a robust and characteristic aroma and flavor, which makes it an essential ingredient during food processing. It is highly valued for its flavor and becomes part of many culinary preparations in the world. The unique characteristics of onion are due to the pungency and distinctive flavor, which accounts for its use as food, salad, spice, condiment, and medicine [2]; [3] and [4]. Nigeria is the world's 6th largest producer of onion, with a production output of over 618,000 tones in the year 2007 [5]. Onion as a vegetable is highly perishable and seasonal, resulting in its relative scarcity during the raining season, which makes onions less available and more expensive [6]. Fresh whole onions can be preserved for a varied period, depending on onion cultivars, bulb size, and storage conditions (temperature and humidity). Whole Onion bulbs have been kept for 2- 4 weeks [7], for 6 months [8], and for 1- 9 months [9]. Once fresh onion bulb is peeled and diced or cut, the shelf life becomes much shorter. Peeled and diced fresh onions can be kept under cold storage for between 10 - 15 days [10]; [11] and [12]. Onions can be processed and preserved when they are cheap and utilized in the off-season in its relative scarcity (during the raining season) when it becomes more expensive. The preharvest scarcity and postharvest gluts are the major limiting factors in the reasonable availability of onion (Allium cepa L) to the consumers [6]. The effect of pickling, canning, boiling, and frying under domestic conditions, dehydration in hot air, freeze-drying, and freezing on the flavor of onion products as compared with that of fresh onions has been investigated [13]. Dehydration is one of the most widely used techniques of preservation of onion. However, The use of thermal treatment can destroy nutrients such as thermally unstable vitamins and also the components responsible for the product's flavor and taste [14] as observed by [15]; and [16]. Today's world market demand for convenience food products is on the increase due to the rapid change in family lifestyles as a result of increasing financial pressure. The old long practice of full housewife is almost nonexistent in urban areas. There is, therefore, a necessary increasing demand for fresh-cut, value-added, and ready-to-eat onion in households, as well as large-scale uses in retail, food service, and various food industries [17]. Value - enhancement in agriculture will not only contribute to the overall economic growth but also provides immediate microeconomics by serving as a source of livelihood for small farmers and foreign exchange-earners for the national economy. Existing and novel techniques have been successfully utilized to extend the shelf life of fresh tomato and onion produce [18]. Onion puree is a favorite type of onion products that can be produced without thermal treatment to prevent loss of quality in terms of color and odor and others [14]. It is a means of preserving fresh onion bulb and also combined the benefits of ease of haulage, packaging, weight reduction and transportation to improve profit margin. Processing of onion into puree will also ease the discomfort commonly experienced while Cutting/chopping onion due to its lachrymatory properties that brings tears to the eyes and odor on the hands [19] and [17]. The irradiation process has been suggested as a way to solve the observed susceptibility of onion puree to spoilage during storage [20]. Consequently, [14] and [26] studied the effect of g-irradiation and γ-irradiation on the physicochemical properties, microbial, and sensory qualities of cold-stored onion. Both authors reported a significant quality improvement; however, irradiation is an expensive method that cannot be economically used for this purpose on any significant commercial scale [22]. Besides, there are ongoing concerns for the safety and nutritional safety of irradiated food, which may hamper its use in those countries (developing countries) likely to benefit most [23]. The use of "hurdle technology," which is to apply more than one technology toward better quality and longer shelf life of food [24], has not been investigated as a technique for onion puree preservation. This technique can help in the efficient processing of raw onion bulbs into a consistently high-quality product for stable all-round the year supply to local markets and supermarkets. Therefore, this research work attempts to produce hurdle preserved onion puree (Hpop) from two cultivars of onions as a convenience product and assessed its sensory and physicochemical properties after storage for thirty (30) days at 4 ± 10 ºC

II MATERIALS AND METHODS

➢ *Collection of Samples*

Matured white and red cultivars of onions, lemon fruit juice, table salt, olive oil, and sugar were purchased at “Shasha” market along Ikere Road, in do -Ekiti, Ekiti State. Nigeria, while the industrial Food grade native cassava starch was obtained from Matna Foods Nigeria Ltd. KLM 19, Akure – Owo expressway Road, Ondo state. Nigeria.

➢ *Onion Puree Preparation.*

10 kg each of sorted whole white and red onions (Allium cepa L**)** was weighed, washed with tap water, and dried using a paper towel. Little olive oil was sprinkled to wet the onion bulbs to prevent sticking during roasting. It was then roasted in a Thermostatic hot air oven at 250 ºC for 30 minutes to enhance the softening of the bulbs and removal of peels and stem. Each onion cultivar was then diced, blended, and acidified by adding fresh lemon juice. The pH was adjusted from an initial pH of 5 – 4.5 until a pH level of < 3.5 was attained. The acidification process was to allow the use of low (below 100 °C) pasteurization temperature [25]. Food grade native cassava starch and sugar as a thickener were then added in a varied proportion to obtain four different treatments for each of the onion cultivars while salt was added to taste. Each of the onion puree samples was then packaged in 25 cl amber plastic bottles, wrapped with foil paper, and pasteurized at 65 °C for 15 mins. The products were then cooled and stored for 30 days, at refrigerator temperature (4±10 ºC) because, according to [26], onion puree quality was more stable at low temperatures (5 ºC) than at higher temperatures (25 ºC).

➢ *pH*

The pH value was determined using a Table digital pH meter, as described by the Association of Official Analytical Chemists [27].

➢ *Determination of Brix*

A digital refractometer calibrated at 0° Brix – 32 °Brix and a resolution of 0.2 was employed to determine the total soluble solid °Brix. The refractometer was first standardized against distilled water. Each of the puree samples was homogenized. The prism was cleaned with soft tissue paper moistened with distilled water; 1 to 2 drops of the sample was then placed on the prism of the refractometer using an eyedropper. The prism lid was then closed and held towards light illumination, and the direct reading was taken by reading the scale and reported as °Brix at 20 °C. After each sample measurement, the prism of the refractometer was cleaned with soft tissue paper moistened with distilled water and dried before re-use.

➢ *Determination of Ascorbic Acid*

Vitamin C was determined using the Iodometric titration procedure, according to the Association of Official Analytical Chemists [28]. 1 ml of each of the puree sample solutions in triplicates was transferred and diluted with distilled water to the mark of 200 ml. 10 ml of each of these solutions was put into a conical flask. To this flask, 5.0 ml of KI solution (0.2 M), 2.5 ml of hydrochloric acid HCl (1.0 M), and a few drops of starch solution were added. Each of the five solutions was then titrated against KIO3 (0.015 M) from the burette until the appearance of blue-black color, which indicates the endpoint of the reaction. The results were recorded, tabulated, and calculated as the ascorbic acid content for each sample.

➢ *Sensory Evaluation*

Appraisal of flavor or pungency of alliums, such as onion (Allium cepa) and garlic (Allium sutiuum), can be based on either subjective sensory analysis or detection of vatization procedure compounds generated by cysteine sulfoxide lyase (C- S lyase; EC 4.4.1 .4) activity after tissue disruption [29]. The Sensory analysis of the Hpop samples was conducted after thirty (30) days storage at 4 ±10 ºC. Freshly prepared white and red onion puree was used as control samples to appraise its sensory properties. Each sample was coded appropriately and presented to twenty (20) semi-trained panelists in random order for sensory evaluation. Approximately 10 g of each sample was served to the panelists and were instructed to rinse their mouth with water tasting each of the samples. The panelists were asked to rate their degree of likes or dislikes of the sensory response variables of color, aroma, taste, and overall acceptability of the samples; using a 9-point hedonic scale (1= dislike extremely, 2 = dislike very much, 3 = dislike moderately, 4 = dislike slightly, 5 = neither like nor a dislike, 6 = like slightly, 7 = like moderately, 8 = like very much, 9 = like extremely)[30]. This test was carried out in the Sensory Evaluation Laboratory of Food Technology Department, The Federal Polytechnic Ado Ekiti, Ekiti State Nigeria.

ISSN No:-2456-2165

➢ *Statistical Analysis*

All data were analyzed using one-way ANOVA from Statistical tool software (SPSS 10). The significance of differences was defined at the 5% significance level ($P < 0.05$).

II. RESULTS AND DISCUSSION

➢ *Sensory properties of onion puree*

The mean score for color, flavor, taste, and overall acceptability of the Hpop and the control samples are presented in Table 1. None of the Hpop was significantly different from the fresh onions puree in terms of taste, color, and general acceptability at $P < 0.05$ irrespective of the onion cultivar except in terms of aroma where it was rated slightly lower than the fresh onion puree. The fresh white onion puree (Wop) was, however, rated highest of all the samples in terms of taste and color with a mean score of 7.70±1.17 and 7.45±1.73, respectively. The fresh red onion puree (Rop) was also rated highest in terms of aroma and overall acceptability with a mean score of 7.35±1.35 and 7.55±1.36, respectively. The Hpop can still be considered shelf-stable after 30 days of cold storage because, according to [31] and [32], Shelf stability of fresh-cut onion can be assessed on either microbial or sensory criteria. The present finding negates the position of [33], who concluded that onion paste without preservatives could only be prolonged up to a maximum of 15 days at refrigerated conditions for acceptable sensorial quality.

Table 1: Sensory Properties of onion puree after 30 days of storage at 4 ± 10 °C

Sample	Aroma	Taste	Colour	Overall Acceptability
Hpopr1	$6.05±1.90^{b,c}$	$7.00±1.70^{a}$	$7.10±1.17^{a}$	$7.45±1.39^{a}$
Hpopr2	$6.45±1.90^{a,b,c}$	$6.50±2.06^{a}$	$6.60±1.50^{a}$	$7.10±1.80^{a}$
Hpopr3	$7.00±1.26^{a,b,c}$	$7.15±1.31^{a}$	$7.00±1.52^{a}$	$7.35±1.35^{a}$
Hpopr4	$5.85±2.43^{c}$	$7.10±1.68^{a}$	$7.00±1.52^{a}$	$7.40±1.31^{a}$
Rop	$7.35±1.35^{a}$	$7.25±1.62^{a}$	$7.25±1.46^{a}$	$7.55±1.36^{a}$
Hpopw1	$7.30±1.34^{a}$	$7.00±1.51^{a}$	$7.25±1.41^{a}$	$7.15±1.56^{a}$
Hpopw2	$6.85±1.79^{a,b,c}$	$7.10±1.45^{a}$	$6.90±2.07^{a}$	$7.50±1.24^{a}$
Hpopw3	$6.30±1.95^{a,b,c}$	$6.65±1.95^{a}$	$7.20±1.40^{a}$	$7.25±1.89^{a}$
Hpopw4	$6.50±1.73^{a,b,c}$	$6.70±1.87^{a}$	$6.65±2.06^{a}$	$7.05±1.93^{a}$
Wop	$7.15±0.93^{a,b}$	$7.70±1.17^{a}$	$7.45±1.73^{a}$	$7.35±1.42^{a}$

Data are mean (SD) of triplicate trials. Different letters in each column indicate that the values differ significantly at $P < 0.05$

➢ *Physiochemical Composition of onion puree.*

The Vitamin C (ascorbic acid) composition of the samples ranged from 2.86 to 10.09 mg/100g. Sample Hpopr1 with 10.09±0.67 and Hpopw1 with 9,82. ±0. 8 mg/100g have significantly higher vitamin C than the fresh onion samples. The Vitamin C content of most of the Hpop is only slightly lesser than that of the fresh sample except for Samples Hpopw4 and Hpopr4. Vitamin C is heat liable, and a significant decrease in the vitamin C content in the product is expected rather than an increase. This increase in vitamin C in some of the Hpop may partly be attributed to the high vitamin C content of the fresh lemon juice used for the product acidification because it is reported that lemon juice contains 36.5 mg/100g Vitamin C [34]. Fresh lemon juice has also been linked with the ability to reduce vitamin C losses during food processing [34] and [35]. Besides, the cassava starch used as a thickener may also contribute to vitamin C retention due to its resistive power to vitamin C oxidation [36]. Interestingly, a progressive increase in the vitamin C retention of the Hpop as the percentage of thickener added increase was observed in the samples for both the red and white onion cultivars. A similar finding was reported from the work of [37], who observed that the vitamin C content of a series of formulated ketchup was highest in the starch added sample compared to the other formulations. The present finding, however, contradicts the decreasing order of vitamin C retention with an increase in the percentage of starch added in the formulated ketchup. The vitamin C content of the fresh red onion puree is higher than that of the fresh white onion puree. A similar pattern was also reported by [38], [39], and [40] among the cultivars of red and white onion from Egypt, Nigeria, and Polish, respectively. Red onion cultivars, therefore, contained significantly more vitamin C than white onion cultivars irrespective of its geographical location. The value of 8.13±0.58 mg/100g vitamin C in the red onion cultivar obtained in the present work is lower than the range of 9.62 - 11.73 mg/100g values obtained by [41] and 14.67 – 18.00 mg/100 reported by [39]. A similar trend was observed for the white onion cultivar. However, the values of vitamin C obtained for both cultivars fall within the range of 5.0 - 10.0 mg/100g fresh weight content in wild onion cultivars reported by [42].

The pH of food indicates the degree of its acidity or alkalinity and plays a significant role in the shelf stability of food. The pH value of the Hpop samples is significantly lower than the pH of the fresh onion puree, which connotes better storability of the product. The values of 3.83±0.02 and 4.32 ±6.00 obtained for the fresh red and white onions, respectively in the present work are lower than the values of 5.65: 5.69 and 5.9: 8.5 for red and white cultivar as reported by [43] and [39] respectively. The observed difference in the pH values of the products, however, has no significant effect on the sensory quality of the products. Brix is an index of the percentage solids (TSS) in a given weight of the material. The ^{o} Brix of a material varies directly with its quality [44]. The Brix content of the Hpop samples ranged from 10.33±0.58 $^{\mathbf{0}}$ to 15.00±00 $^{\mathbf{0}}$. The Brix content of the samples Hpopr1 and Hpopw1 are significantly higher than that of the fresh onion puree; this can be attributed to the thickener added. The significant difference in the degree Brix values of 12.00±0.00 and 10.67±0.29 obtained for the fresh red and white onion puree respectively in the present work agreed with the reported variations ranged value of between 8.2 - 12.2 and 8.83 – 9.73 degree Brix in fresh red and white onions varieties respectively [45] and [39] but with higher values of total solids except in the value for the white cultivars reported by [45]. However, [46] reported that the total soluble solids among thirty genotypes of onion varied from 9.13 - 14.1 percent, with an overall mean of 11.87 %, which is very close to the mean value of 11.34% obtained in the present study. The observed difference in the total solids of the two cultivars can be attributed to the influence of cultivar varieties on the postharvest quality characteristics of onion bulbs [41]. The Brix (total soluble sugar) content of the red onion variety puree is significantly higher than that of the white onion, this was also reported by [45]

ISSN No:-2456-2165

Table 2. Physiochemical composition of onion puree after 30 days of storage at 4 ± 10 °C.

Sample	Vitamin C(mg/100 g)	^{0}Brix	pH
Hpopr1	10.09±0.67^{a}	15.00±0.00^{a}	3.39±0.00^{e}
Hpopr2	7.96±1.01^{c}	12.33±0.58 ^{b}	3.53±0.00^{cd}
Rop	8.13±0.58^{c}	12.00±0.00^{bc}	3.83±0.02^{b}
Hpopr3	7.87±035^{c}	12.33±0.58^{b}	3.52±0.02^{cd}
Hpopr4	2.86±0.25 ^{e}	12.33±0.58^{b}	3.57±0.06^{cd}
Hpopw1	9.82± 0.8 $^{a\,b}$	14.93±0.58^{a}	3.55±0.10^{cd}
Hpopw2	8.62 ±0. 67^{bc}	10.65±0.58^{de}	3.56±0.11^{cd}
Wop	7.20 ±1. 54^{cd}	10.67±0.29^{de}	4.32 ±6. 00^{a}
Hpopw3	6.22±0.85^{d}	10.33±0.58^{e}	3.49±0.02^{d}
Hpopw4	2.98±0.73^{e}	10.67±0.58^{de}	3.62±0.02^{c}

Data are mean (SD) of triplicate trials. Different letters in each column indicate that the values differ significantly at $P < 0.05$.

KEY

Hpopr1 = 75 % Red onion, 20 % starch and 5 % sugar

Hpopr2 = 85 % Red onion, 10 % starch and 5% sugar

Rop = 100 % Fresh red onion puree

Hpopr3 = 90 % Red onion, 5 % starch and 5% sugar

Hpopr4 = 92.5 % Red onion, 2.5 % starch and 5 % sugar

Hpopw1 = 75 % White onion, 20 % starch and 5 % sugar

Hpopw2 = 85 % white onion, 10 % starch and 5% sugar

Wop = 100 % Fresh white onion puree

Hpopw3 = 90% White onion, 5 % starch and 5% sugar

Hpopw4 = 92.5 % white onion, 2.5 % starch and 5 % sugar

III. CONCLUSION

Hpop as a value-added product without the addition of any conventional preservatives showed a promising result. The sensory and physiochemical quality of the Hpop is not only favorably comparable to the fresh onion samples; the vitamin C content in some of the developed samples is significantly higher than that of the fresh onion after thirty (30) days cold storage. The present finding suggests that the production of Hpop as a convenience product for households, canteen, and other culinary uses with acceptable quality is achievable. The product will not only improve the continuous access to affordable onion products all year round; it will also empower the peasant onion farmers, and processors since the processing technology can be domesticated.

ACKNOWLEDGMENT

This research study was sponsored by the Tertiary Education Trust Fund [TetFund], Nigeria under Institutional Based Research Grant [IBR] and The Centre for Research Innovations and Development [CRID] of The Federal Polytechnic Ado Ekiti, Ekiti State, Nigeria (FPA/CRID/TRG/31/169)

REFERENCES

[1]. M. Corzo-Martínez, N. Corzo, and M. Villamiel, “Biological properties of onions and garlic,” *Trends Food Sci. Technol.*, vol. 18, no. 12, pp. 609–625, 2007, doi: 10.1016/j. tiffs. 2007.07.011.

[2]. M. Ali, M. Thomson, and M. Afzal, “Garlic and onions: Their effect on eicosanoid metabolism and its clinical relevance,” *Prostaglandins Leukot. Essent. Fat. Acids*, vol. 62, no. 2, pp. 55–73, 2000, doi: 10.1054/plef. 1999.0124.

[3]. G. Griffiths, L. Trueman, T. Crowther, B. Thomas, and B. Smith, “Onions - A global benefit to health,” *Phyther. Res.*, vol. 16, no. 7, pp. 603–615, Nov. 2002, doi: 10.1002/ptr. 1222.

[4]. W. C. Hurst, R. L. Shewfelt, and g. A. Schuler, “Shelf-Life and Quality Changes in Summer Storage Onions (Allium cepa),” *J. Food Sci.*, vol. 50, no. 3, pp. 761–763, 1985, doi: 10.1111/j. 1365-2621.1985. tb13791. x.

[5]. I. M. Sulumbe, B. G. Shettima, and T. B. John, “An analysis of the marketing of onion in Monguno local government area of Borno State, Nigeria,” *J. Mark. Consume. Res.*, vol. 13, pp. 9–14, 2015.

[6]. K. Raju and M. K. Naik, “Effect of post-harvest treatments of onion to control spoilage during storage,” *J. Food Sci. Technol.*, vol. 44, no. 6, pp. 595–599, 2007.

[7]. S. B. Dodson, G. Student, F. Science, and V. Tech, “Safe Handling and Storing of Raw Fruits and Vegetables,” p. 4, 2016.

[8]. L. Mogren, *Quercetin Content in Yellow Onion (Allium cepa L.) Effects of Cultivation Methods, Curing, and Storage*. 2006.

[9]. D. H. And O. A. Jonathan SG, Olawuyi OJ, Aina DA, “Influence of storage time on biodeterioration, aflatoxin contamination and food values of onion (Allium cepa) *Jonathan,” *Nat. Sci.*, vol. 10, no. 11, pp. 26–32, 2012.

[10]. L. R. Howard, k. S. Yoo, l. M. Pike, and g. H. Miller, “Quality Changes in Diced Onions Stored in Film Packages,” *J. Food Sci.*, vol. 59, no. 1, pp. 110–112, 1994, doi: 10.1111/j. 1365-2621.1994. tb06909. x.

[11]. N. D. Berno, J. V. Tezotto-Uliana, C. T. dos Santos Dias, and R. A. Kluge, “Storage temperature and type of cut affect the biochemical and physiological characteristics of fresh-cut purple onions,” *Postharvest Biol. Technol.*, vol. 93, pp. 91–96, 2014, doi: 10.1016/j. postharvest. 2014.02.012.

[12]. S. Bhuvaneswari, C. K. Narayana, R. Udhayakumar, and R. V. Gowda, “Effect of packaging and storage temperature on the shelf-life of minimally processed onion (Allium cepa L.),” *J. Hortic. SCI.*, vol. 10, no. 2, pp. 216–219, 2015.

[13]. G. G. Freeman and R. J. Whenham, “Changes in Onion,” pp. 499–515, 1974.

[14]. N. Sadoughi, R. Karim, D. M. Hashim, A. Zainuri, and H. M. Ghazali, “Effect of γ-irradiation on the physicochemical properties, and microbial and sensory qualities of cold-stored onion puree,” *J. Food Process. Preserve.*, vol. 37, no. 5, pp. 889–898, 2013, doi: 10.1111/j. 1745-4549.2012.00739. x.

[15]. A. Sangwan, A. Kawatra, and S. Sehgal, “Nutritional Evaluation of Onion Powder, Dried Using Different Drying Methods,” *Asian J. Dairy Food Res.*, vol. 29, no. 2, pp. 151–153, 2015.

[16]. G. Mazza and m. Lemaguer, “Dehydration of onion: some theoretical and practical considerations,” *Int. J. Food Sci. Technol.*, vol. 15, no. 2, pp. 181–194, 1980, doi: 10.1111/j. 1365-2621.1980. 00930. x.

[17]. M. Bahram-Parvar and L. T. Lim, “Fresh-Cut Onion: A Review on Processing, Health Benefits, and Shelf-Life,” *Compr. Rev. Food Sci. Food Saf.*, vol. 17, no. 2, pp. 290–308, 2018, doi: 10.1111/1541-4337.12331.

[18]. S. S. Nassarawa, S. A. Sulaiman, and K. State, “Extending the shelf life of tomato and onion in Nigeria: A review,” pp. 99–111, 2019.

[19]. S. A. Petropoulos, G. Ntatsi, and I. C. F. R. Ferreira, “Long-term storage of onion and the factors that affect its quality: A critical review,” *Food Rev. Int.*, vol. 33, no. 1, pp. 62–83, 2017, doi: 10.1080/87559129.2015.1137312.

[20]. R. A. Molins, Y. Motarjemi, and F. K. Käferstein, “Irradiation: A critical control point in ensuring the microbiological safety of raw foods,” *Food Control*, 2001, doi: 10.1016/S0956-7135 (01)00035-4.

[21]. N. Sadoughi, R. Karim, D. M. Hashim, A. Zainuri, and H. M. Ghazali, “Combined Effects of γ-Irradiation and Ascorbic Acid on the Physicochemical Properties, Microbial Stability and Aroma Profile of Onion Puree During Storage,” *J. Food Process. Preserve.*, vol. 39, no. 6, pp. 645–652, 2015, doi: 10.1111/jfpp. 12272.

[22]. C. J. S. Bakker-Arkema, F. W, J. DeBaerdemaeker, P. Amirante, M. Ruiz-Altisent, *Fruit and Vegetable Quality*, vol. IV. The American Society of Agricultural Engineers, 1999.

[23]. W.H.O, “Safety and Nutritional adequacy of Irradiated food.,” WHO L1brary Cataloguing in Publication Data Safety, 1994.

[24]. I. S. Arvanitoyannis, A. C. Stratakos, P. Tsarouhas, I. S. Arvanitoyannis, and A. C. H. Stratakos, “Irradiation Applications in Vegetables and Fruits: A Review Irradiation Applications in Vegetables and Fruits: A Review,” vol. 8398, 2009, doi: 10.1080/10408390802067936.

[25]. J. S. B. Wu and S. C. Shen, *Processing of Vegetable Juice, and Blends.* New Jersey, Wiley-Blackwell: 2011.

[26]. J. Ahmed and U. S. Shivhare, “Thermal kinetics of color degradation and storage characteristics of onion paste,” *LWT - Food Sci. Technol.*, vol. 34, no. 6, pp. 380–383, 2001, doi: 10.1006/fstl. 2001.0771.

[27]. A.O.A.C, *Official methods of analysis of the association of official analytical chemists*, vol. 242. Washington D.C, 1991.

[28]. AOAC, Official Methods of Analysis of AOAC International, 18th Ed., no. February. GAITHERSBURG, MARY LAND 20877-2417, USA, 2006.

[29]. D. J. Thomas, K. L. Parkin, and P. W. Simon, “Development of a simple pungency indicator test for

onions," *J. SCI. Food Agric.*, vol. 60, no. 4, pp. 499–504, 1992, doi: 10.1002/jsfa. 2740600415.

[30]. A. L. Wszelaki, J. F. Delwiche, S. D. Walker, R. E. Liggett, S. A. Miller, and M. D. Kleinhenz, "Consumer liking and descriptive analysis of six varieties of organically grown edamame-type soybean," *Food Qual. Prefer.*, vol. 16, no. 8, pp. 651–658, 2005, doi: 10.1016/j. food qual. 2005.02.001.

[31]. D. Rico, A. B. Martín-Diana, J. M. Barat, and C. Barry-Ryan, "Extending and measuring the quality of fresh-cut fruit and vegetables: a review," *Trends Food Sci. Technol.*, vol. 18, no. 7, pp. 373–386, 2007, doi: 10.1016/j. tiffs. 2007.03.011.

[32]. F. Liu and Y. Li, "Storage characteristics and relationships between microbial growth parameters and shelf life of MAP sliced onions," *Postharvest Biol. Technol.*, vol. 40, no. 3, pp. 262–268, 2006, doi: 10.1016/j. postharvest. 2006.01.012.

[33]. S. Arefin, M. Bhuiyan, N. Yeasmen, M. Islam, and M. S. U. Din, "Study of ready to use onion paste for prolonged shelf life," *Progress. Agric.*, vol. 30, no. 2, pp. 219–226, 2019, doi: 10.3329/pa. v30i2. 42518.

[34]. T. M. Khumbo and G. M. Kingsley, "Effect of lemon juice treatment and sun drying on vitamin C retention in three steam and water blanched indigenous vegetables over six weeks storage period," *African J. Food Sci.*, vol. 8, no. 6, pp. 316–321, 2014, doi: 10.5897/ajfs2014. 1167.

[35]. A. Musa and E. O. Ogbadoyi, "Effect of Processing Methods on Some Micronutrients, Antinutrients and Toxic Substances in Hibiscus Sabdariffa," *Asian J. Crop Sci.*, 2012, doi: http://dx.doi.org/10.3923/ajb.2012.63.79.

[36]. R. Jumah, S. Al-Asheh, F. Banat, and K. Al-Zoubi, "Influence of salt, starch and pH on the electroosmosis dewatering of tomato paste suspension," *J. Food, Agric. Environ.*, vol. 5, no. 1, pp. 34–38, 2007.

[37]. K. Alam, M. Ahmed, S. Akter, N. Islam, and J. B. Eun, "Effect of carboxymethylcellulose and starch as thickening agents on the quality of tomato ketchup," *Pakistan J. Nutr.*, vol. 8, no. 8, pp. 1144–1149, 2009, doi: 10.3923/pjn. 2009.1144.1149.

[38]. Y. A. Elhassaneen and M. I. Sanad, "Phenolics, selenium, vitamin C, amino acids and pungency levels and antioxidant activities of two Egyptian onion varieties," *American Journal of Food Technology*, vol. 4, no. 6. Pp. 241–254, 2009, doi: 10.3923/ajft. 2009.241.254.

[39]. B. A. Akinwande and S. J. Olatunde, "Comparative evaluation of the mineral profile and other selected components of onion and garlic," *Int. Food Res. J.*, vol. 22, no. 1, pp. 332–336, 2015.

[40]. G. Jurgiel-Malecka, M. Gibczynska, and M. Nawrocka-Pezik, "Comparison of the chemical composition of selected cultivars of white, yellow and red onions," *Bulg. J. Agric. SCI.*, vol. 21, no. 4, pp. 736–741, 2015.

[41]. O. S. Jolayemi, S. S. Nassarawa, O. M. Lawal, M. A. Sodipo, and I. B. Oluwalana, "Monitoring the changes in chemical properties of red and white onions (Allium cepa) during storage," vol. 9, no. September, pp. 78–86, 2018, doi: 10.5897/JSPPR2018.0263.

[42]. Lawande K. E, *Onion Handbook of Herbs and Spices*. Woodhead Publishing, Oxford, 2011

[43]. U.P.Onyeoziri, E.N, Romans, and U.I Onyekachukwu, "Assessment of antioxidant capacities and phenolic contents of Nigerian cultivars of onions (Allium cepa l) and garlic (Allium sativum l)," *Pak. J. Pharm. SCI.*, vol. 29, no. 4, pp. 1183–1188, 2016, doi: 10.4172/2472-0542-C1-012.

[44]. R. Harrill, "Using a refractometer to test the quality of fruits & vegetables," p. 28, 1994.

[45]. B. A. Kandoliya, U.K., Bodar, N.P., Bajaniya, V.K., Bhadja N.V., and Golakiya, "Determination of nutritional value and antioxidant from bulbs of different onion (Allium cepa) variety : A comparative study," *Int. Journal Curr. Microbiol. Appl. SCI.*, vol. 4, no. 1, pp. 635–641, 2015.

[46]. P. Singh, A. K. Soni, P. Diwaker, and A. R. Meena, "Genetic Variability Assessment in Onion (Allium cepa L.) Genotypes," *Int. J. Chem. Stud.*, vol. 5, no. 5, pp. 145–149, 2017.