A STUDY ON THE VOLATILE CONTENT AND SENSORY ATTRIBUTES OF CONVECTIVE-DRIED ONION POWDERS

Sneha Mishra[1], Prof. (Dr.) Akhand Pratap Singh[2], Dr. Nidhi Mishra[3]
[1]Ph.D Research Scholar, Department of Biotechnology, Maharishi University of Information Technology, Lucknow, Uttar Pradesh, India
sneha.hbti2010@gmail.com
[2]Maharishi University of Information Technology, Lucknow, Uttar Pradesh, India,
akhand73@rediffmail.com
[3]Associate Professor, Applied Science, Indian Institute of Information Technology, Prayagraj, Uttar Pradesh, India
nidhimishra2979@gmail.com

KEYWORDS
Onion, Volatile content, sensory attributes, Convective dried etc.

ABSTRACT
Convective drying is easy to use and reasonably priced, it is the method most frequently employed to produce dry onion products. However, volatile chemicals in fresh onions may easily evaporate during convective drying, particularly if the drying process is carried out at a high temperature. Utilizing laminar drying at various temperatures, the volatile content and ultimate perceptive quality of dried onions with associated features were examined. During convective drying, the volatile content and sensory characteristics of onion samples changed. It was discovered that the primary volatile component in fresh onions, dipropyl disulfide, is what gives them their green color after onions were new, and sulfides, notably di-propyl disulfide, seemed to be the main odor components; however, these compounds drastically diminished after the onions dried.

INTRODUCTION

Allium cepa bulbs have natural enzymes including polygalacturonates and pectin methyl esterase that cause them to easily soften and are vulnerable to illnesses following harvesting. One of the best ways to prolong the shelf life of onions is to dry them out so they can be chipped or powdered. A wide range of commercial products, such as sauces, snacks, frozen foods, and retorted goods, frequently use dry onions as an ingredient. Volatile chemicals, in general, influence the sensory qualities of food products overall, which frequently determines their acceptance and eating quality.

The relationship between volatile ingredients and food sensory attributes has been the subject of numerous researches, which have demonstrated the significance of mercurial composition for sensory attributes.

Sulfur-based components are important volatiles in fresh onions, and they are formed by the action of an innate enzyme called alliinase. Similar volatile chemicals have been identified for both dry and fresh onion products. With the help of this enzyme, S-alk(en)ly-L-cysteine sulfoxide is hydrolyzed to create volatile sulfur compounds, such as mono, di, and trisulfides.

Different aldehydes have also been found to be another class of volatile substances in fresh onions. It is common knowledge that fruits and vegetables include a variety of aldehydes, which are essential components of scent.

Because fats are the substrates of the enzymes lipoxygenase and hydroperoxide lyase, which are responsible for the synthesis of aldehydes, the majority of volatile aldehydes have six to nine carbons.

However, some volatile aldehydes can cause an off-flavor, particularly if their residual concentrations are excessively high. Numerous studies have examined the impact of various drying techniques, including vacuum, convection, sunlight, and microwaves, on the nutritional value of items made from dried onions.

Because convective drying is easy to use and reasonably priced, it is the method most frequently employed to produce dry onion products. However, volatile chemicals in fresh onions may easily evaporate during convective drying, particularly if the drying process is carried out at a high temperature.

Onion variations in volatile chemicals and sensory attributes during convective drying, however, have not been the subject of any research. Utilizing laminar drying at various temperatures, the volatile content and ultimate perceptive quality of dried onions with associated features were examined.

THE COMPONENTS AND PROCEDURES

Fresh Allium Cepa was bought from a local market. The PDMS/DVB-coated solid-phase micro-extraction fiber, the C7–C40 saturating the alkanet usual substances 1000 µg/mL in hexane and allyl methyl sulfide, onions were cut into approximately 3 mm slices using a stainless steel knife, 120 grams of the onion slices were evenly spread on a stainless steel tray, the dried out the onion samples were then ground into powder in a mortar filled with liquid nitrogen, the moisture content of the powders was ascertained by drying, the color of the onion powders was measured with a colorimeter.

SOLID-PHASE MICRO-EXTRACTION VIA HEADSPACE NEEDED:

The volatile chemicals in dried and fresh onion samples were analyzed by HS-SPME, following the methodology of a prior work with only slight adjustments. A 20-mL glass vial was filled with five grams of either freshly ground onion powder or a suspension made from water of dried onion powder. A concentration of allyl methyl sulfide was dissolved in distilled water to create an internal standard solution. After that, a 20 µL aliquot was added to the vial. After quickly sealing the vial with a PEFE-silicone septum, it was magnetically agitated for 30 minutes at 25 C.

GC–MS ANALYSIS:

A gas chromatography connected to an MS mass spectrometer (MS) was used to identify volatile chemicals. On a DB-Wax column, the volatile substances that the SPME fiber extracted were separated. Using an SPME liner, heat was applied in a spotless manner for five minutes at 250 C to facilitate the desorption of heat into the injector. Temperature in the GC oven was adjusted to 45 ºC for 10 min, and then raised to 200 ºC at an average of 6 ºC per minute, and held there for 5 min. As a carrier gas, helium was employed at a steady flow rate of 1 mL/min. At 70 eV, the mass detector ran in the electron impact (EI) mode.

A minimum matching factor of 80% was used to compare the mass spectrum of unknowns with those in the Wiley 07 library to make tentative identifications. By comparing each component's linear retention index (RI) to that of reference compounds RI was calculated using C7 to C40 alkenes standards the identities of the constituents were verified.

SENSORY ANALYSIS

To profile the key odor features of onion samples, an analytical analysis of sensation (DSA) was performed. Samples of fresh onions and dried onions produced at 50 degrees Celsius for 12 hours (CD50_12H) and 90 degrees Celsius for 3 hours (CD90_3H) were selected for sensory analysis due to significant differences in the overall quantity about reactive sulfur and aldehyde in these samples.

In blind trials, the panelists experienced both young and dehydrated onion samples and engaged in a discussion on olfactory qualities throughout training sessions. By consensus, they came up with a final list of 11 descriptive terms.

The general intensity and attractiveness of the odor were assessed, along with its pungent, humid, sulfurous, green in color, fat, burnt, earthy, cooked vegetable, sweet, onion, and caramel qualities.

Samples were prepared for the correlation study in the same manner as they were for SPME. Two samples were used for each analysis, and the DSA was carried out in triplicate throughout a scoring line that went between 0 to 9.

FINDINGS AND DISCUSSION

Eighteen compounds that are volatile were found by meeting both the comparison RI and the matching factor (80%). The present study's examination was unable to confirm the RI responses of dimethyl sulfide, 2-methylbutanal, and 3-methylbutanal due to their tiny size. Aldehydes or sulfur compounds made up each and every volatile chemical that was found. The majority of Allium species include these two chemical groups, which are thought to be the cause of their distinctive flavors. In fresh onions, the sulfur compounds made up 98.30% of all volatile compounds, while the aldehydes were present in far lesser amounts.

According to Jones et al. (2004), fresh onions contain a variety of taste precursors, including S-methyl cysteine sulfoxide, trans-S-1-propenyl cysteine sulfoxide, and Spropyl cysteine sulfoxide. Alliinase converts these precursors into the majority of volatile sulfur compounds. Onions' sulfur components, however, easily evaporate when they dry.

The chemical structures of all the sulfur compounds found in this investigation are either sulfide or thiophene. Dipropyl disulfide made up 77.70% of the volatile chemicals in fresh onions, out of all the volatile components.

However, drying significantly reduced the amount of this sulfur compound, which was in accord. Regarding the dehydrated onion samples, it was notable that the samples dried at 90°Celsius, had the largest quantities of total sulfur compounds.

As the onion samples were dried at 90° Celsius, the concentration of sulfur compounds rose. Additionally, the dried onion samples contained certain novel sulfides that had not been discovered in the freshest onion, which included dimethyl sulfide or dimethyl trisulfide. particularly at high drying temperatures.

Fresh onions' flavor precursors may have been thermally degraded, leading to the creation of sulfur compounds. According to reports, S-methyl-cysteine may decompose into a-amino-acrylic acid and methyl-sulfenic acid. Dimethyl thio-sulfinate is created when methyl sulfuric acid self-condenses. It can then be converted producing dimethyl disulfide and dimethyl thio-sulfonate.

Furthermore, it was noted that a crucial route for the synthesis of dimethyl trisulfide was the degradation by itself of dimethyl thio-sulfinate. As a result, throughout the three hours of thermal drying at 90^0 Celsius, the levels of dimethyl disulfide and dimethyl trisulfide rose to 6.86 with 66.74 μg/g solids at the same accordingly, whereas the concentration of dimethyl sulfide steadily dropped.

Data showed that the convective drying method used to prepare dry onion powders caused thermal degradation of taste precursors in fresh onions, suggesting that dimethyl sulfide may have changed into the presence of dimethyl disulfide and dimethyl trisulfide. Thus, it was expected that thermal dried-out onions would have a different flavor character than fresh onions.

Another important class of taste chemicals in onions is aldehydes. Nine aldehydes were found in samples of dried and fresh onions. When onions had been air-dried at around fifty degrees Celsius over twelve hours, the overall aldehyde concentration seemed to be highest, and when onions were fresh, it appeared to be lowest.

Fresh onions contained hexanal, 2-methyl 2-pentenyl, and [E]-2-heptanol, which made up 1.70 percent of all volatile chemicals. During the drying process, the composition and content of aldehyde significantly changed.

In both the raw and dried onion samples, 2-methyl 2-pentenal was the most common aldehyde, with concentrations fluctuating between 19.9 to 144 μg/g compounds. The sequential transformation of 1-propenyl sulfuric acidic substances to thio-propanal-S-oxide, which in turn transforms into 2-methyl 2-pentenal, yields 2-methyl 2-pentenal.

As draining duration and temperature rose, more aldehydes, such as 2-methylbutanal and 3-methylbutanal, were produced. 2-methylbutanal and 3-methylbutanal were the byproducts of Strecker's breakdown of Iso-leucine and leucine, respectively.

It was so discovered that after scallions were dried with hot air, the amount of these two amino acids that remained decreased. All the aldehydes found in this investigation are known to have a major role in giving different vegetables their distinctive aromas.

Remaining enzymes like lipoxy-genase and hydro-per-oxide lyase converted fatty acids into aldehydes. Enzymes may become inactive at temperatures above 65^0Celsius. Whereas their activity may increase at drying temperatures of 50^0Celsius.

PRINCIPAL COMPONENT EVALUATION (PCE):

The biplot diagram of the first two main elements, which accounted for 80.44% of the variance, was used to assess the relationship between drying conditions and volatile compounds. This method of analysis may help recognize volatile compounds that are shipped between the samples that were prepared under various conditions. 52.71% of the variance was explained by the very first principal component (PC1).

Sulfur compounds and aldehydes were the principal forces pushing it in the positive and negative directions, respectively. The amount of all the aldehydes in the samples processed at 50 and 70 degrees Celsius had been greater than that of fresh onions and specimens dried at 90^0Celsius and these samples were grouped on the contrary axis of PC1.

SENSORY ASSESSMENT

To ascertain how drying conditions affected the onion samples' sensory characteristics, an exploratory sensory analysis (DSA) was performed. The primary flavor attributes of fresh onions are onion 7.25, green 4.56, and pungent 5.89.

When compared to fresh onions, the onion sample that had been dried at 50°C for 12 hours had a significantly lower green attribute, but no discernible change in the pungent and onion qualities. This sample has the highest humidity characteristic, which may have been brought about by the sample's highest concentration of aldehydes.

When compared to fresh onions, the onion sample that endured drying at the hottest temperature showed a substantial drop in qualities related to sharp (p 0.05), bright green ($p < 0.001$), and onion ($p < 0.001$).

The fat, burnt, sweet, and caramel descriptors showed significant improvements (p less than 0.001) in this condition. Additionally, the intense heat treatment increased the potency ($p < 0.05$) of various flavor qualities, including cooked, sulfurous veggies and attractiveness.

Many volatile substances, some of which were not found in this investigation, may result from the browning reaction brought on by high-temperature drying. These substances were thought to produce the characteristic smells of caramel, sweetness, and bluntness found in browning items.

RELATIONSHIP BETWEEN SENSORY CHARACTERISTICS AND VOLATILE CHEMICALS

The link between 18 volatile chemicals and 13 sensory qualities, such as general intensity and attractiveness, was investigated using Pearson correlation. An off-flavor in onion powder was thought to be the humidity characteristic, which seemed to have a considerably positive link with the 2-methyl-2-pentanal and hexanal, which showed tight correlations with samples in PCA.

A prior study found that when the overall amount of aldehydes is high, off-flavor may be produced. The flavor of fresh and spring onions has been attributed to 2, 5-dimethylthiophene, which showed strong relationships with the samples. This molecule showed strong connections with the flavors of caramelized sugar, burnt fat, sweet potatoes, and cooked vegetables when compared to a prior study.

The compound with the highest abundance, 3, 4-Dimethylthiophene, likewise showed strong associations with buttery and sweet characteristics. Specifically, the aldehydes that exhibited an association with the samples were 2-methylbutanal and 3-methylbutanal; burnt and caramel flavors have been attributed to them. Fresh onions contained a lot of chemicals that were volatile, and di-propyl disulfide was strongly correlated with the green characteristic.

It has been suggested that this chemical gives fresh leek and strong raw onion flavors. The results indicate that there was a significant difference in the volatile content between fresh and dried onion samples, and there was also a lack of perfect correlation between the volatile composition and the onion samples' sensory qualities.

In onion samples, the volatile chemical compounds exist as mixtures, and because these compounds interact with one another to produce distinct qualities, it is difficult to anticipate the sensory properties from the mixtures. More research should be done on the connections between flavor perception and the volatile composition of samples of dried onions so that they can be used in gastronomy.

Table 1: Experimental Data (Source: So Mang Choi et al 2017)

Onion Origin	Seoul, Korea.
Fiber	Make : PDMS/DVB-Coated, Made: Supelco (Bellefonte, PA
Onion Slice thickness	3 mm
Total Mass of Onions	120 grams
Tray Dimensions	31 cm X 22 X 2 cm Material : Stainless Steel
Convective Dryer	Make : Mov-112F Made : Sanyo, Japan
Drying Time	2.5 to 48 hours
Drying Temperatures	50 to 90^0 Celsius with intervals of 20^{0}Celsius.
Colorimeter	Make : CR-10; Konica Minolta Made : Sensing Inc. Japan
Stirring Process	25^{0}Celsius , 30 minutes
Gas Chromatography	Make: 7890A, Made: Agilent Technologies, Santa Clara,CA
Mass Spectrometer	Make:5975C, Made: Agilent Technologies
Wax Column	Length = 30 Meters , Inside Diameter = 0.25 Millimeters,Film Thickness = 0.25 µm Made : J&W Scientific, Agilent

Table 2: Fresh Onion Specimens Processed Beneath Various Circumstances Were Examined For Humidity Quantity. (Source: So Mang Choi et al 2017)

Drying Time (hours)	Moisture Content (%) Maximum	Minimum
0	92.42	91.32
	DT @50^{0}Celsius	
12	16.15	15.73
24	14.31	14.44
48	12.81	12.59
	DT @ 70^{0}Celsius	
4.5	16.01	15.69
6	13.59	13.47
10	12.74	12.46
	DT @ 90^{0}Celsius	
2.5	16.03	15.69
2.66	13.61	13.37
3	12.57	12.35

Moisture Content: (Maximum)

Referring to Table 2: Graph 1, 2 and 3 the maximum deviations in moisture content are inversely proportional with the drying hours as well as drying temperature. In case of drying temperature 50^{0}Celsius the maximum dryness content is available at 12 hours as 16.15 %. In case of drying temperature 70^{0}Celsius the maximum dryness content is available at 10 hours as 16.01 %. In case of drying temperature 90^{0}Celsius the maximum dryness content is available at 2.5 hours as 16.03%.

Moisture Content: (Minimum)

Referring to Table 2 Graph 4, 5 and 6 the maximum and minimum deviations in moisture content are inversely proportional with the drying hours as well as drying temperature. In case of drying temperature 50^{0}Celsius the minimum dryness content is available at 48 hours as 12.59% In case of drying temperature 70^{0}Celsius the minimum dryness content is available at 10 hours as 12.46 %. In case of drying temperature 90^{0}Celsius the minimum dryness content is available at 3 hours as 12.35%.

Table 3: Onion Specimens Processed Beneath Various Circumstances Were Examined For Measure of Brown Index (Source: So Mang Choi et al 2017)

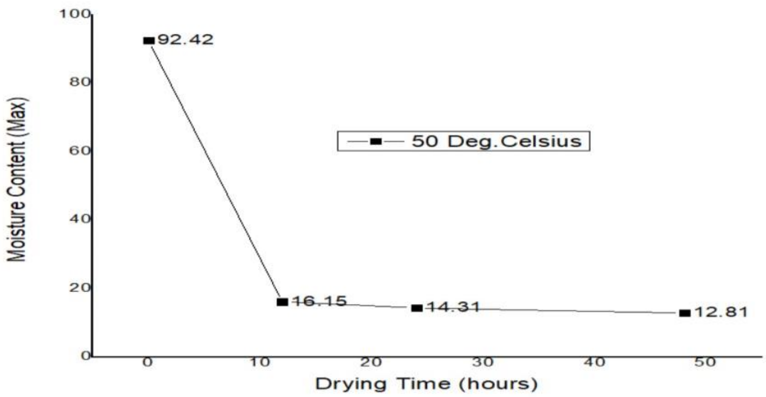
Drying Time (hours)	Brown Index Maximum	Brown Index Minimum
0	27.63	23.89
DT @50^{0}Celsius		
12	31.16	29.2
24	32.16	30.24
48	32.23	30.81
DT @ 70^{0}Celsius		
4.5	38.13	36.55
6	44.94	36.48
10	47.25	43.81
DT @ 90^{0}Celsius		
2.5	54.66	51.26
2.66	59.95	57.93
3	67.75	63.33

Brown Index (Maximum):

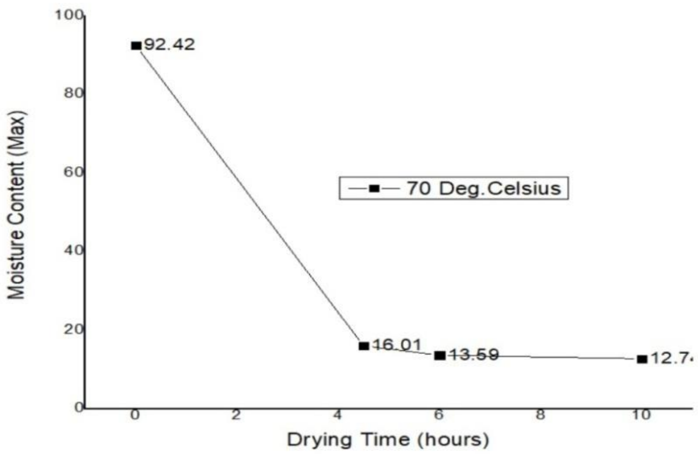
Referring to Table 3 Graph 7, 8 and 9 the maximum deviations in Brown Index are directly proportional with the drying hours as well as drying temperature. In case of drying temperature of 50^{0}Celsius the maximum Brown index value is available at 48 hours as 30.81. In case of drying temperature, at 70^{0}Celsius the maximum Brown Index is available at 10 hours as 47.25 and in case of drying temperature 90^{0}Celsius the maximum Brown index value is available at 3 hours as 67.75

Brown Index (Minimum):

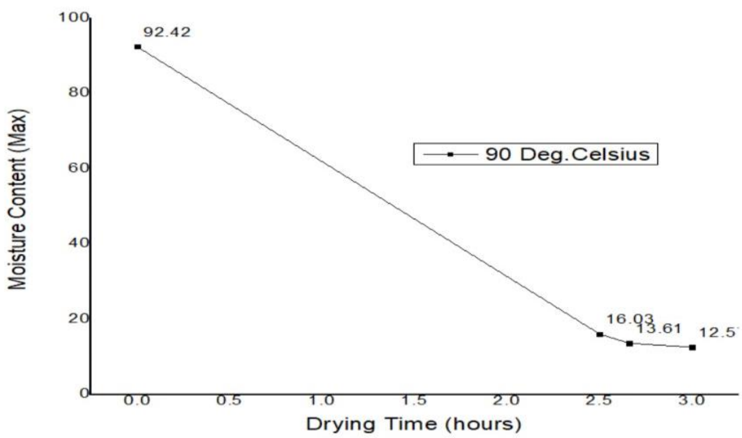
Referring to Table 3 Graph 10, 11 and 12 the minimum deviations in Brown Index are directly proportional with the drying hours as well as drying temperature. In case of drying temperature of 50^{0}Celsius the minimum Brown index value is available at 12 hours as 29.2. In case of drying temperature, at 70^{0}Celsius the minimum Brown Index is available at 4.5 hours as 36.55 and in case of drying temperature 90^{0}Celsius the minimum Brown index value is available at 2.5 hours as 51.26.



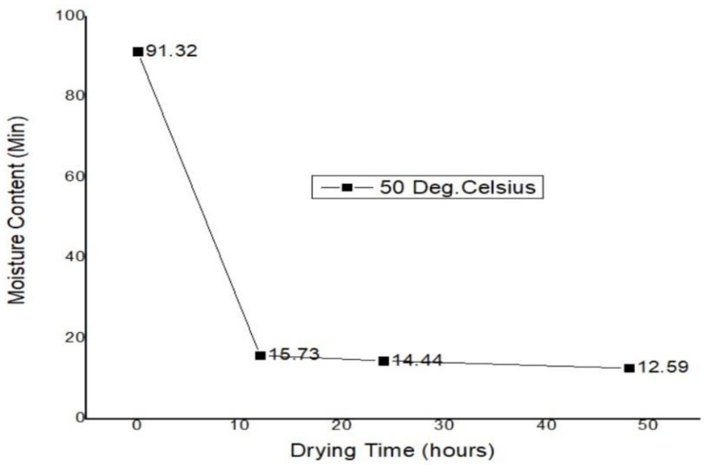
Graph 1: Deviations of Drying Time Vs Max. Moisture Content with Reference to Drying Temperature 50^{0}Celsius



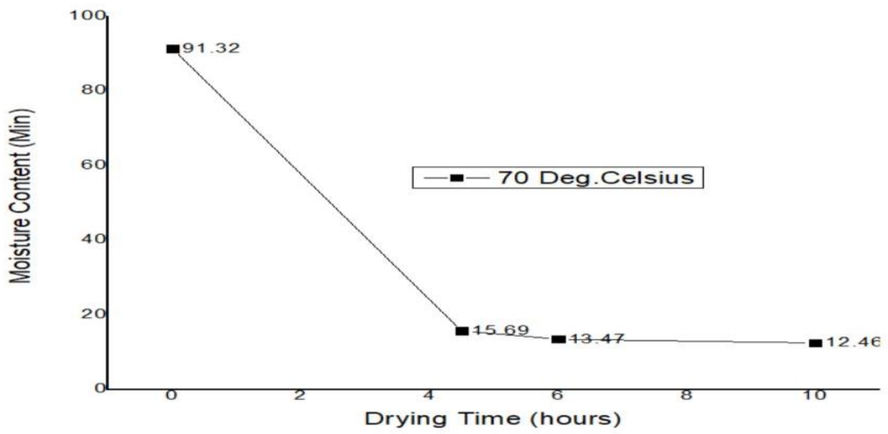
Graph 2: Deviations of Drying Time Vs Max .Moisture Content with Reference to Drying Temperature 70^{0}Celsius



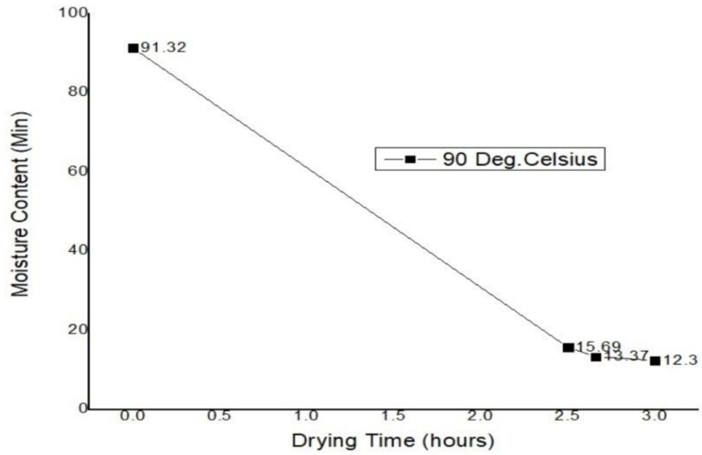
Graph 3 Deviations of Drying Time Vs Max .Moisture Content with Reference to Drying Temperature 90^{0}Celsius



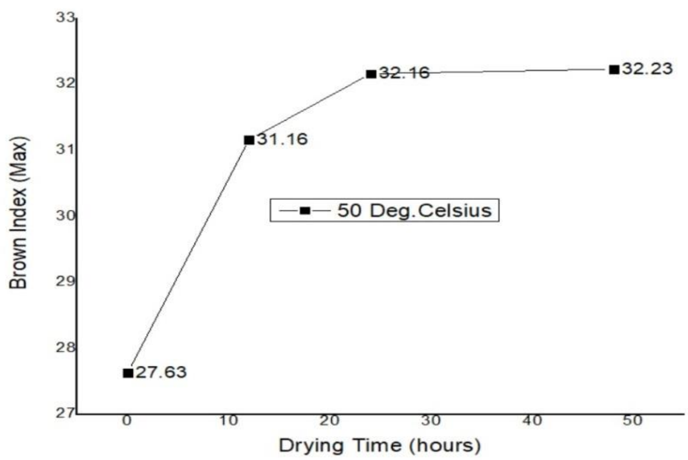
Graph 4 Deviations of Drying Time Vs Min. Moisture Content with Reference to Drying Temperature 50^{0}Celsius



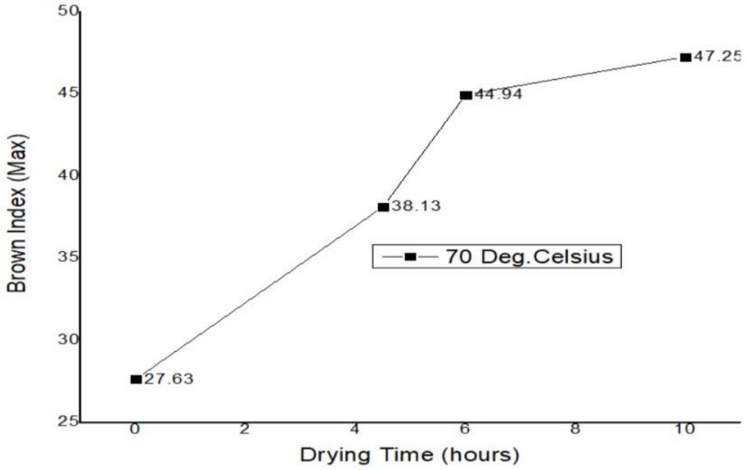
Graph 5: Deviations of Drying Time Vs Min. Moisture Content with Reference to Drying Temperature 70^{0}Celsius



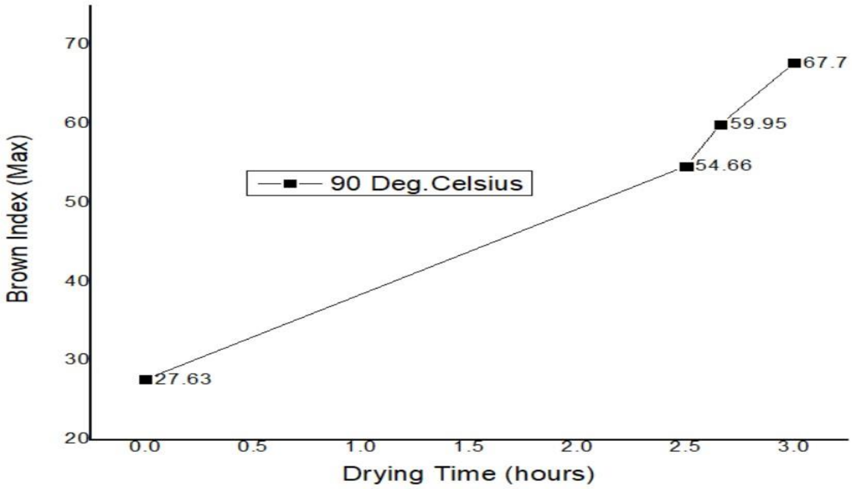
Graph 6: Deviations of Drying Time Vs Min. Moisture Content with Reference to Drying Temperature 90^{0}Celsius



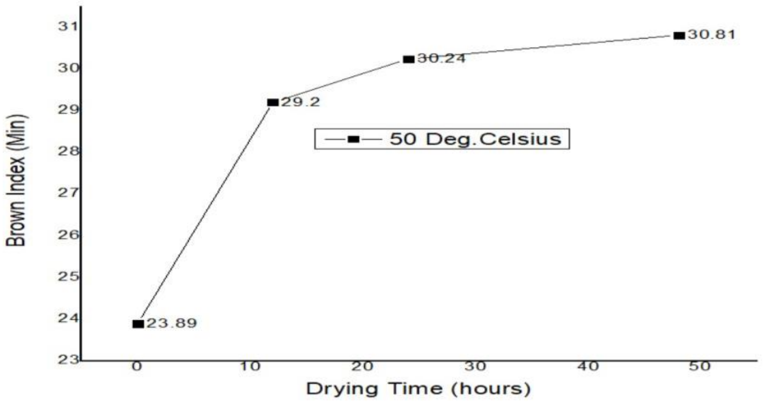
Graph 7: Deviations of Drying Time Vs Max. Brown Index with Reference to Drying Temperature 50^{0}Celsius



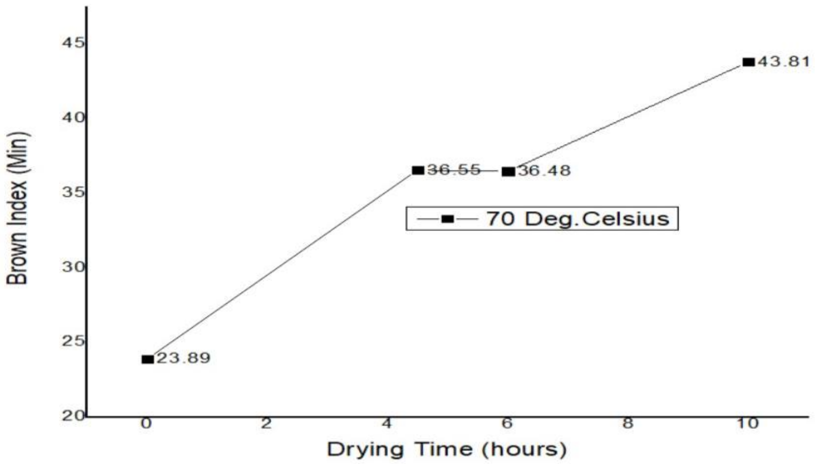
Graph 8: Deviations of Drying Time Vs Max. Brown Index with Reference to Drying Temperature 70^{0}Celsius



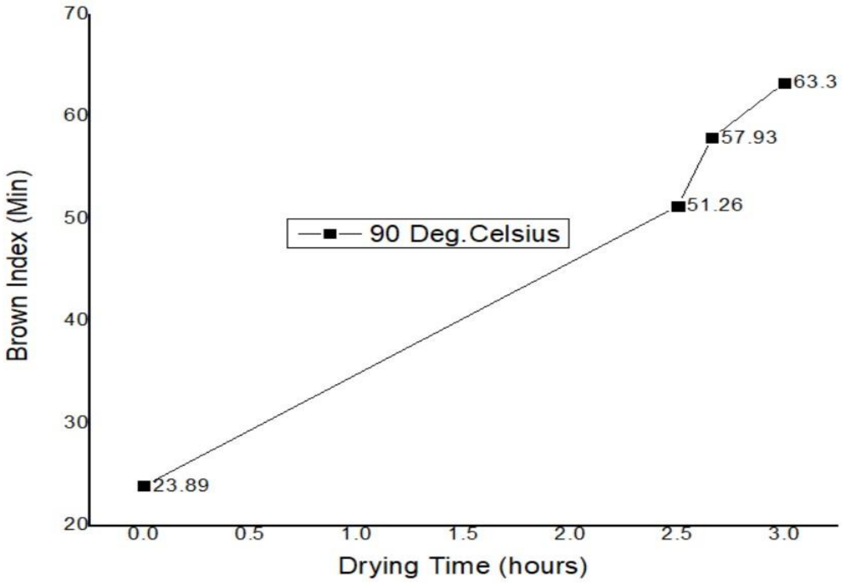
Graph 9: Deviations of Drying Time Vs Max. Brown Index with Reference to Drying Temperature 90^{0}Celsius



Graph 10 Deviations of Drying Time Vs Min. Brown Index with Reference to Drying Temperature 50^{0}Celsius.



Graph 11:Deviations of Drying Time Vs Min. Brown Index with Reference to Drying Temperature 70^{0}Celsius



Graph 12 Deviations of Drying Time Vs Min. Brown Index with Reference to Drying Temperature 90^{0}Celsius.

CONCLUSION

During convective drying, the volatile content and sensory characteristics of onion samples changed. It was discovered that the primary volatile component in fresh onions, dipropyl disulfide, is what gives them their green color after onions were new, and sulfides, notably di-propyl disulfide, seemed to be the main odor components; however, these compounds drastically diminished after the onions dried. However, when onions were dried at a reasonably high temperature, the majority of sulfur compounds rose perhaps as a result of heat deterioration. Caramel, burnt, fat, sweet, and cooked vegetable characteristics were caused by 2, 5-dimethylthiophene, which showed strong connections between it and onion samples dried at 90^0 Celsius.

These aldehydes were in charge of the humidity characteristic. The complex combination of these substances, which showed both masking and synergistic effects, seems to be responsible for the overall sensory quality of the dried onion samples rather than the individual volatile compounds. It seemed that mild drying conditions and comparatively moderate temperatures were the best for preserving the fresh onion scent.Remaining enzymes throughout the drying process created aldehydes, among them 2-methyl-2-pentenal and hexanal, particularly when the specimens were left to air dry at low temperatures. It was discovered that the drying conditions and temperatures had a big impact on the sample moisture loss rates. The product dried more quickly in a microwave oven than it did under the other assay-specific drying conditions.

The largest Deff values were obtained by microwave drying, which was almost 50 times greater compared to the results of sun and oven 50^0 Celsius drying. When drying in the sun, the reading of Deff was 1.12 times higher than when drying in an oven at 50^0 Celsius.Compared to sun and oven drying, microwave drying in the oven with a low energy output 210 Watts could preserve the product's phenolics. The technique and drying temperature had an impact on the variations in mineral concentrations.

The dried sample's mineral content increased with time via oven drying at 70 °Celsius relative to other dried samples.The best color values were found by sun drying and using a 210 watts microwave oven. The least acceptable color values were produced by oven drying at 70^0Celsius plus microwave drying at 700 Watts. Therefore, it is often advised to use low-temperature oven drying when evaluating the process's economics.This crucial moisture content is the point where onion powder stores exceptionally well for an extended amount of time.

REFERENCES

1. Chang, H.-S., Yamato, O., Yamasaki, M., Ko, M., & Maede, Y. (2005). Growth inhibitory effect of alk(en)yl thiosulfates derived from onion and garlic in human immortalized and tumor cell lines. Cancer Letters, 223(1), 47–55. https://doi.org/10.1016/j.canlet.2004.10.008
2. Malla, A., Srinivasan, B., Shanmugaraj, B. M., & Ramalingam, S. (2015). Micropropagation and DNA delivery studies in onion cultivars of Bellary, CO3. Journal of Crop Science and Biotechnology, 18(1), 37–43. https://doi.org/10.1007/s12892-014-0101-6
3. Prakash, D., Singh, B. N., & Upadhyay, G. (2007). Antioxidant and free radical scavenging activities of phenols from onion (Allium cepa). Food Chemistry, 102(4), 1389–1393. https://doi.org/10.1016/j.foodchem.2006.06.063
4. Yang, J., Meyers, K. J., van der Heide, J., & Liu, R. H. (2004). Varietal differences in phenolic content and antioxidant and antiproliferative activities of onions. Journal of Agricultural and Food Chemistry, 52(22), 6787–6793. https://doi.org/10.1021/jf0307144
5. Siddiq, M., Roidoung, S., Sogi, D. S., & Dolan, K. D. (2013). Total phenolics, antioxidant properties and quality of fresh-cut onions (Allium cepa L.) treated with mild-heat. Food Chemistry, 136(2), 803–806. https://doi.org/10.1016/j.foodchem.2012.09.023
6. Lombard, K., Peffley, E., Geoffriau, E., Thompson, L., & Herring, A. (2005). Quercetin in onion (Allium cepa L.) after heat-treatment simulating home preparation. Journal of Food Composition and Analysis, 18(6), 571–581. https://doi.org/10.1016/j.jfca.2004.03.027
7. Dorant, E., van den Brandt, P. A., & Goldbohm, R. A. (1995). Allium vegetable consumption, garlic supplement intake, and female breast carcinoma incidence. Breast Cancer Research and Treatment, 33(2), 163–170. https://doi.org/10.1007/bf00682723
8. Crozier, A., Lean, M. E. J., McDonald, M. S., & Black, C. (1997). Quantitative Analysis of the Flavonoid Content of Commercial Tomatoes, Onions, Lettuce, and Celery. Journal of Agricultural and Food Chemistry, 45(3), 590–595. https://doi.org/10.1021/jf960339y
9. Gyamfi, M. A., Yonamine, M., & Aniya, Y. (1999). Free-radical scavenging action of medicinal herbs from Ghana. General Pharmacology: The Vascular System, 32(6), 661–667. https://doi.org/10.1016/s0306-3623(98)00238-9
10. Ninfali, P., & Bacchiocca, M. (2003). Polyphenols and Antioxidant Capacity of Vegetables under Fresh and Frozen Conditions. Journal of Agricultural and Food Chemistry, 51(8), 2222–2226. https://doi.org/10.1021/jf020936m
11. Pérez-Gregorio, R. M., García-Falcón, M. S., Simal-Gándara, J., Rodrigues, A. S., & Almeida, D. P. F. (2010). Identification and quantification of flavonoids in traditional

cultivars of red and white onions at harvest. Journal of Food Composition and Analysis, 23(6), 592–598. https://doi.org/10.1016/j.jfca.2009.08.013

12. Nuutila, A. M., Puupponen-Pimiä, R., Aarni, M., & Oksman-Caldentey, K.-M. (2003). Comparison of antioxidant activities of onion and garlic extracts by inhibition of lipid peroxidation and radical scavenging activity. Food Chemistry, 81(4), 485–493. https://doi.org/10.1016/s0308-8146(02)00476-4
13. Choi, S. M., Lee, D.-J., Kim, J.-Y., & Lim, S.-T. (2017). Volatile composition and sensory characteristics of onion powders prepared by convective drying. Food Chemistry, 231, 386–392. https://doi.org/10.1016/j.foodchem.2017.03.129
14. Zhao, X.-X., Lin, F.-J., Li, H., Li, H.-B., Wu, D.-T., Geng, F., Ma, W., Wang, Y., Miao, B.-H., & Gan, R.-Y. (2021). Recent Advances in Bioactive Compounds, Health Functions, and Safety Concerns of Onion (Allium cepa L.). Frontiers in Nutrition, 8. https://doi.org/10.3389/fnut.2021.669805
15. Hanahan, D., & Weinberg, R. A. (2000). The Hallmarks of Cancer. Cell, 100(1), 57–70. https://doi.org/10.1016/s0092-8674(00)81683-9
16. Lisanti, A., Formica, V., Ianni, F., Albertini, B., Marinozzi, M., Sardella, R., & Natalini, B. (2015). Antioxidant activity of phenolic extracts from different cultivars of Italian onion (Allium cepa) and relative human immune cell proliferative induction. Pharmaceutical Biology, 54(5), 799–806. https://doi.org/10.3109/13880209.2015.1080733
17. Murayyan, A. I., Manohar, C. M., Hayward, G., & Neethirajan, S. (2017). Antiproliferative activity of Ontario grown onions against colorectal adenocarcinoma cells. Food Research International, 96, 12–18. https://doi.org/10.1016/j.foodres.2017.03.017
18. Bahram-Parvar, M., & Lim, L.-T. (2018). Fresh-Cut Onion: A Review on Processing, Health Benefits, and Shelf-Life. Comprehensive Reviews in Food Science and Food Safety, 17(2), 290–308. https://doi.org/10.1111/1541-4337.12331
19. Singh, B. N., Singh, B. R., Singh, R. L., Prakash, D., Singh, D. P., Sarma, B. K., Upadhyay, G., & Singh, H. B. (2009). Polyphenolics from various extracts/fractions of red onion (Allium cepa) peel with potent antioxidant and antimutagenic activities. Food and Chemical Toxicology, 47(6), 1161–1167. https://doi.org/10.1016/j.fct.2009.02.004
20. Tiwari, U., & Cummins, E. (2013). Factors influencing levels of phytochemicals in selected fruit and vegetables during pre- and post-harvest food processing operations. Food Research International, 50(2), 497–506. https://doi.org/10.1016/j.foodres.2011.09.007
21. Bystrická, J., Musilová, J., Vollmannová, A., Timoracká, M., & Kavalcová, P. (2013). Bioactive components of onion (Allium cepa L.) — a Review. Acta Alimentaria, 42(1), 11–22. https://doi.org/10.1556/aalim.42.2013.1.2
22. Sellappan, S., & Akoh, C. C. (2002). Flavonoids and Antioxidant Capacity of Georgia-Grown Vidalia Onions. Journal of Agricultural and Food Chemistry, 50(19), 5338–5342. https://doi.org/10.1021/jf020333a