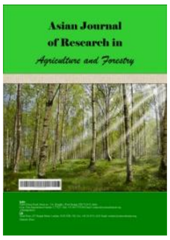

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Effects of Some Drying Methods on the Quality of Dried Nigerian Onion Varieties

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

This research aimed to study the effects of some drying methods on the qualities of dried Nigerian onion varieties. Sliced onion samples of 1.5kg from each variety were dried in the three dryers at varying pre-determined temperatures of 50, 60, and 70°C. At 50, 60, and 70°C, the electrically powered dryer dried red onion for 13.55, 12.10, and 10.30 h, dried white onion for 14.10, 12.25, and 10.55 h, and dried cream onion for 14.10, 13.15, and 11.35 h. The kerosene-powered dryer at 50, 60, and 70°C dried red onion for 14.45, 13.22, and 11.55 h, dried white onion for 14.50, 13.15, and 11.15 h, and dried cream onion for 14.25, 13.05, and 12.20 h. The solar dryer at 57°C dried red onion for 72.45, dried white onion for 72.20 h, and dried cream onion for 72.50 h. Therefore, using kerosene, solar, and electrically powered dryers significantly affects onion quality (constituents and flavor). However, the electrically powered dryer could attain the required temperature quickly and further maintained the temperature, which proved to be the best method for drying the onions at 70°C.

Keywords: Drying; temperature; onion; quality; varieties.

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1. INTRODUCTION

Sun-drying is the simplest method of drying. The heat of the sun and movement of the air remove moisture, which causes drying. The limitation of sun drying is that onion does not control drying time and exposes the food to insect attack and contaminations to sand and dirt. This technology depends totally upon the weather conditions [1]. Sun drying of crops is cheap compared to other methods of drying because solar energy is free. Solar drying is similar to sun drying because they both depend on the heat of the sun for drying crops. However, solar dryers involve using simple construction to more efficiently use the heat of the sun. Like the sun drying, they rely solely on the availability of sunlight. They are thus only appropriate in areas with a suitable climate: high levels of sunshine and low relative humidity. Under the proper climatic condition, solar drying has the following advantages over sun drying: eliminate long days of the drying period, excessive colour fading, and contamination by dust, insect, and other microorganisms commonly associated with open-air during drying practices in most rural communities. In solar drying, solar air heating may be direct, in which the air is heated in the drying chamber containing the food, or indirect, using an external collector to heat the air.

Cabinet drying utilizes trays to expose the product to the heated air in an enclosed space. The trays holding the product inside a cabinet of similar enclosures are exposed to heated air as the dehydration proceeds. Air movement over the product surface occurs at relatively high velocities to ensure that the heat and mass transfer proceeds in an efficient manner [2]. This method is faster than sun/solar drying, and products are generally of high quality. Batch oven dryers are substantially the same as tray dryers. In tray dryers, the food is spread out thinly on trays in which the drying takes place. The trays in the oven dryer are enclosed in a large cabinet that is evacuated. Heating may be an air current sweeping across the trays by conduction from heated trays or heated shelves on which the tray lies or radiation from heated surfaces. Most trays are heated by air, and this also removes the vapour. The electric oven, which is a type of cabinet dryer, was used in this research work.

Puff drying is a relatively new process that has been applied successfully to several fruits and vegetables [1]. This process is accomplished by exposing a relatively small piece of the product to high pressure, and the product is moved to atmospheric pressure. This results in flash evaporation of water and allows vapour from the interior parts of the drier to escape. The rapid moisture evaporation and resulting product porosity contribute to prompt moisture removal during the final drying stage. Products produced by puff-drying have very high porosity with quick rehydration characteristics. Puff drying is particularly effective for products with significant falling-rate drying periods [3]. The puff-drying process is accomplished most efficiently by using 2 cm cube shapes. These pieces will dry rapidly and uniformly and will rehydrate within 15 minutes. Although the process may not apply to all foods, the superior quality encourages additional investigation of the process [4].

A second relatively new design for drying solid particle foods is fluidized bed drying. In this system, the pieces of the product are suspended in the heated air throughout the time required for drying. The effect created by fluidized particles results in equal drying from all products surfaces [4]. Air from the fluidized bed is usually fed into a cyclone to separate fine particles. The primary limitation of the fluidized bed process is the size of the particles that will allow efficient drying. As expected, smaller particles can be maintained in suspensions with lower air velocities and dry more rapidly [1].

The drying of liquid food products is often accomplished in a spray dryer. Moisture removal from a liquid is atomized or sprayed into heated air within a drying chamber (Fellow, 1998). While liquid food droplets move with the heated air, the water evaporates and is carried away by air. Much of the drying occurs during a constant-rate period and is limited by mass transfer at the droplet's surface. After reaching, the critical moisture content, the dry food particle surfaces influence the falling-rate drying period. During this portion of the process, moisture diffusion within the particle becomes the rate-limiting parameter. After the dry food particles leave the drying chamber, the product is separated from the air in a cyclone separator [2]. The dried product is then placed in a sealed container at moisture contents usually below 5%. Product quality is considered excellent due to the protection of products solids by evaporative cooling in the spray dryer. The small particle size of dried solids promotes easy reconstitution when mixed [4].

Another drying system involves using a microwave oven to bring about a drying effect on a food sample that brings about a uniform, rapid, and energy-efficient method compared to conventional hot air drying [5]. The microwave penetrates to the interior part of the food causing water to get heated within the food. This results in a significantly increased vapour differential between products at the center and those at the side, allowing lowing trap moisture removal from the food to be dried. Example of food dried by microwaves includes fruits and vegetables (tomatoes, okra, garden egg, etc.). It is one of the most exciting drying methods in terms of mechanism and economics for heating and drying of various food products.

Inyang [6] has reported that lack of adequate knowledge of storage techniques and postharvest handling of onions by these local farmers results in onion losses of up to 69% annually. This drastically reduces the annual income of onion farmers. Also, the end-users, primarily housewives, pay more for a unit of onion at times of scarcity. There is little documented research work on the drying of onions in Nigerian. This research aimed to study the effects of some drying methods on the qualities of Nigerian onions.

2. MATERIALS AND METHODS

The three onion varieties, white, red, and cream onions, were obtained from National Institute for Horticultural Research (NIHORT) Kano sub-station, Nigeria. The moisture contents of red, white, and cream onions were 87%, 85.1%, and 88.2%, respectively.

2.1 Drying Equipment

The drying equipment used for the research work include solar cabinet dryer, kerosene powered dryer, and electrically-powered dryer, which are all locally fabricated.

2.1.1 Solar dryer

A locally fabricated solar dryer was used for drying the prepared onion slices. The solar cabinet dryer consist of a collector (made of transparent glass of 5mm thickness) positioned directly on the drying chamber to trap solar energy for direct drying. The drying chamber, which houses three drying trays, has a dimension 60 x 45 x 60 cm (length x width x height). The drying trays are made of galvanized mesh welded to a one-inch square pipe. The trays were covered with drying nets before the sliced onions were spread on them. Plate 1 shows open and closed views of the dryer. Vents for the discharge of moisture-laden air are located at the sides of the cabinets.

2.1.2 Kerosene powered dryer

The kerosene-powered dryer consisted of a drying chamber (90 x 60 x 60 cm^3) mounted on top of the combustion chamber housing the kerosene stoves. The combustion chamber is separated from the drying chamber by a heat exchanger. The kerosene stove heats the bottom pot attached to the heat exchanger dividing the combustion chamber from the drying chamber to prevent direct contact of flames with the product. A fan powered by a battery recharged by a solar panel through a solar converter circulated the heated air in the drying chamber. A hot wire anemometer and a thermocouple were attached to the drying chamber to measure air velocity and drying temperature. The drying chamber housed three drying trays (83 x 51 cm^2), which consisted of a fine mesh aluminum screen stretched across a strip steel frame. The heated air temperature could only be regulated by adjusting the stoves' wick/thread until set temperatures of 50, 60, and 70^oC were achieved as NSPRI [7] recommended. Plate 2 shows open and closed kerosene powered dryers.

2.1.3 Electrically powered dryer

The electrically powered dryer consisted of a drying chamber (95 x 65 x 65 cm) mounted on a combustion chamber with two heating elements. A fan powered by a 1.5 kW permanent magnet DC motor (Dayton Electric MnSg.Nites.IL) circulates air in the drying chamber. The heating elements are connected to electricity via a thermostat through which the temperature of the drying chamber can be regulated. The air velocity for all the drying tests was set at 0.5 m/s. The drying chamber housed five drying trays with an area (86 x 52 cm^2) each. It consisted of a fine mesh galvanized screen stretched across a strip steel frame. An aluminum waveguide rested on top of the drying tray and surrounded the product sample. Prepared onion samples were spread on the trays in thin layers with the drying temperature set at 50, 60, and 70^0C. The front view of the electrically powered dryer is shown in Plate 3.

Plate 1. Open and closed solar dryer

Plate 2/ Open and closed kerosene powered dryer

Plate 3. Electrically-powered dryer

2.2 Research Methodology

All the varieties were subjected to the same process. Onion was cleaned by removing the top and bottom, the dry outer layers, and the first fleshy layer, which accounted for about 20% of the onion to achieve the consistent composition of onion slices. Root, stems, and the dry outer layers of the onions have a lower moisture content, more microbial contamination, and more significant flavour component variation than the bulb's inner section [8,9,10]. Cleaned onions were sliced perpendicular to the axis into pieces 3mm thick using a stainless steel knife. This slice thickness was chosen based on the thickness used by commercial dehydrators. The slice with the perpendicular cutting could have a higher drying rate due to the greater area for moisture removal than the parallel cutting [11,12]. The slices were maintained intact in all drying experiments as recommended by Al-Katary [2]. Initial and dry onions were analyzed for protein, fat Ash, crude fibre, moisture, and vitamin C contents. Vitamin C was determined using the 2,6-dichlorophenol indophenols method [13]. The Official Analytical Method [13] was used to determine other protein, fat, crude fibre, and moisture content parameters. Moisture content was calculated on a dry weight basis. Pungency was measured using a chemical pyruvic acid assay outlined by Anthon and Barrett [14]. Tryptic Soy Agar was used to determine the aerobic plate count. Dicholroan Rose Bengal Chloramphenicaol agar (DRBC) was used to enumerate yeast and mould populations. Consumer acceptability and colour changes were monitored and scored on a 1-3 basis with the verdict or test panel drawn from a cross-section of end-users of onion, namely; housewives, food vendors, and Suya sellers using the scale below:

Key:

Consumer Acceptability Score

1 = good as fresh one
2 = almost as good as fresh
3 = not as good as fresh
Colour Change score:
1 = Very bright
2 = almost bright
3 = not bright

The results obtained were statistically analyzed using One Way classified Variance data while statistical significance was considered significant at $p < 0.05$.

For the control, a tarpaulin sheet was spread on top of a raised platform in an open space. As in the case of a normal sun drying method, the samples were spread on the tarpaulin under the sun and left to dry. At sunset, the samples were taken in-door and returned at sunrise the following day. This routine was maintained until the onion was dried to the moisture content of 24.7%.

3. RESULTS AND DISCUSSION

3.1 Effect of Drying Methods on the Proximate Composition of the Onion Varieties

The proximate composition of fresh and dried onion samples is presented in Tables 1 – 3. The changes in moisture content, protein, fat, vitamins C contents were found to be very significant for the three drying methods, especially at 70 ºC. Decreases in moisture content and vitamins were the most noticeable changes in onion after drying. This trend is in agreement with the results by Sharma and Nath [15].

The Tables also show the relative significant changes that occurred using kerosene and electrically powered dryer at 70ºC, and solar at 50ºC in drying the onion samples. A higher temperature in drying onions and other vegetables certainly has significant effects on vitamins and minerals, as Yaldiz and Ertekin [16] reported. Vitamin C content was high at the beginning of the drying period and decreased significantly during drying. This is due to the unstable nature of Vitamin C when exposed to high temperatures. This agreed with Sharma et al. [17], who reported that Vitamin C losses increased as the duration of drying was extended in Ziziphus Mauritiona (Lamk). The same trend was observed in the Vitamin C content of dried tomatoes as reported by Idah et al. [18] and Rahman and Perera [19].

Retention of vitamin C contents in onion drying is significantly higher in solar than electric and kerosene because of the gradual low-temperature process in solar drying. However, the table also observed that some onion constituents are lost during drying no matter how mild the temperature. This also agreed with the report of Jayaraman and Das Gupta [20]. Proteins, Ash, Fibre, and Fat contents increased as shown in the tables because of the concentration of nutrients in dried products. Heat increases protein content due to product dehydration that concentrates protein, thus increasing the nutritional value of the dried onions. A similar trend is observed in other food products such as fish and tomatoes, as reported by Ahmed et al. [21] and Idah et al. [18]. Similarly, the increase in crude fibre, fat, and ash contents in the dried onions can be attributed to moisture removal, which leads to the concentration of all nutrients in the dried onions. These results agree with earlier studies by Aliya et al. (2012) in fish and meat products.

Table 1. Proximate composition (per 100 g) of fresh and dried red onion

Proximate composition	Fresh	Electric (70ºC)	Kerosene (70ºC)	Solar (50ºC)
Moisture (%)	87.3	6.3	7.3	11.20
Protein (%)	1.5	10.4	10.7	11.6
Ash (%)	0.6	3.5	3.7	3.9
Fibre (%)	0.5	5.8	6.1	6.7
Carbohydrate (%)	8.7	80.5	80.7	80.9
Energy value (j/kg)	160	1459	1461	1465
Vitamins B-carotene equiv. (µg)	328	-	-	-
Thiamine (mg)	0.04	-	-	-
Riboflavin(mg)	0.02	-	-	-
Niacin (mg)	0.3	-	-	-
Ascorbic acid (mg)	10	-	-	-
Magnesium(mg)	-	124	127	129
Potassium(mg)	-	943	945	948
Sodium (mg)	-	55	57	54
Fat (g)	0.5	1.3	1.6	1.8
Phosphorous (mg)	41	343	347	349

Table 2. Proximate composition (per 100 g) of fresh and dried white onion

Proximate composition	Fresh	Electric (70ºC)	Kerosene (70ºC)	Solar (50ºC)
Moisture (%)	85.1	6.4	7.5	12.10
Protein (%)	1.5	10.3	10.5	10.7
Ash (%)	0.6	3.4	3.6	3.6
Fibre (%)	0.5	5.6	5.9	5.7
Carbohydrate (%)	8.7	80.7	80.5	80.8
Energy value (j/kg)	160	1458	1456	1458
Vitamins B-carotene equiv.(µg)	328	-	-	-
Thiamine (mg)	0.04	-	-	-
Riboflavin(mg)	0.02	-	-	-
Niacin (mg)	0.3	-	-	-
Ascorbic acid (mg)	10	-	-	-
Magnesium(mg)	-	124	126	127
Potassium(mg)	-	945	947	945
Sodium (mg)	-	56	55	57
Fat (g)	0.5	1.3	1.5	1.7
Phosphorous (mg)	41	342	344	347

Table 3. Proximate composition (per 100 g) of fresh and dried cream onion

Proximate composition	Fresh	Electric (70ºC)	Kerosene (70ºC)	Solar (70ºC)
Moisture (%)	88.4	6.4	7.8	12.54
Protein (%)	1.5	10.3	10.4	10.5
Ash (%)	0.6	3.3	3.4	3.7
Fibre (%)	0.5	5.6	5.7	5.6
Carbohydrate (%)	8.7	80.3	80.4	80.2
Energy value (j/kg)	160	1454	1456	1459
Vitamins B-carotene equiv. (µg)	328	-	-	-
Thiamine (mg)	0.04	-	-	-
Riboflavin(mg)	0.02	-	-	-
Niacin (mg)	0.3	-	-	-
Ascorbic acid (mg)	10	-	-	-
Magnesium(mg)	-	123	125	124
Potassium(mg)	-	945	946	944
Sodium (mg)	-	55	56	55
Fat (g)	0.5	1.3	1.4	1.5
Phosphorous (mg)	41	342	344	346

3.2 Drying Characteristics of Dried Onion Varieties

The data from the three drying methods are presented in Table 4. This drying schematic allowed for the rapid achievement of high temperatures. Still, it caused significant undesirable quality changes in the products concerning the browning of the onion samples, especially at a low temperature of 50ºC for a more extended drying period. This is consistent with other research work carried out by Lee et al. [22].

The solar drying permitted the reabsorption of moisture by the products, thereby increasing the moisture content of the products. This could be as a result of condensation taking place in the drying chamber during the night period. The colour of the white onion samples was very bright, while that of red and cream onion samples was faded. This could be attributed to the bleaching effect of direct solar energy on the products. When the drying process was terminated because of the samples constant weight measurement after 73h of drying, the products was further subjected to further drying, which did not make any difference in the moisture content of all the onion varieties. This showed the limitation of this method of drying onion to obtain a safe moisture content of less than 8%.

Table 4. Drying of the three varieties of onions at different temperatures and time

Drying Methods	Variety	Initial moisture content %	Temperature (ºC)	Drying time (hr)	Final moisture content %
Electric	Red onion	87.3	50	13.55	6.7
			60	12.10	6.5
			70	10.30	6.3
	White onion	85.1	50	14.10	6.8
			60	12.25	6.6
			70	10.55	6.4
	Cream onion	88.4	50	14.35	6.9
			60	13.15	6.6
			70	10.25	6.4
Kerosene	Red onion	87.3	50	14.45	7.3
			60	13.27	7.0
			70	11.55	6.8
	White onion	85.1	50	14.50	7.5
			60	13.15	7.3
			70	11.15	7.0
	Cream onion	88.4	50	14.25	7.8
			60	13.05	7.3
			70	12.20	7.1
Solar	Red onion	87.3	57	96.45	11.20
	White onion	85.1	57	96.20	12.10
	Cream onion	88.4	57	96.50	12.54

The kerosene-powered drying of onion samples had a similar drying characteristic with that of the electrically powered drying since both drying methods experienced a continuous heating process. The electrically powered dryer recorded a faster drying rate. This could be attributed to the electrically powered dryer having the capacity to quickly attain the required drying temperature and maintain the temperature for a more extended drying period. In all the drying processes, it is evident from the drying curves and the chemical parameter tables that the moisture content decreased continuously with the drying time. This decrease in moisture contents can be attributed to moisture loss due to an increase in temperature, which agrees with an earlier study by Akbari and Patel [23]. As expected, the air temperatures had significant ($p > 0.05$) effects on the moisture contents of the samples, which are consistent with the report of Sharma and Nath [15].

The moisture content decreased rapidly in the early drying stage when electric drying was used compared to kerosene drying. This might be due to the quicker time for the heating elements to attain the pre-determined temperature than that of the kerosene and solar, resulting in faster moisture removal from the samples. A greater drying rate was obtained with electric than kerosene and solar at the latter drying stage. The drying rate varied with the drying temperature as expected. For each of the plots from the electric drying tests, a constant rate period was absent. This could be caused by the hygroscopic nature of onions, which immediately entered the falling rate period. This is in agreement with the research report by Rahman and Perera [19].

The electric drying tests showed a distinct rate period at each of the three temperatures tested than the kerosene and solar. The same effect was seen in convection drying of onions by Schiffman. [24]. The electric dryer used continuous heating, which was independent of changes in the product-specific heat. Therefore, the electric dryer maintained steady heat fluxes throughout drying. The constant air movement could also explain this higher rate in the electric drying in the electric drying caused by its blowers which assisted in moisture removal at the end of the drying process. The drying rate is generally higher for electric than the kerosene drying within the first six hours, about 52 g of moisture was removed from the products dried in the kerosene dryer while 67 g was removed from those dried in the electric dryer during this period. This shows that although the two drying systems attain the same temperature, the mechanism of moisture removal in the electric dryer is better, which can be attributed to control heating

3.3 Effect of Process Conditions on Drying Rate for all the Drying Trials

The Analysis of Variance (ANOVA) for drying rate is as presented in Table 5. From the ANOVA table, it can be inferred that the process conditions (temperature, drying methods, and drying rate) and the interactions between these three factors had a significant effect on the drying rate of onion at 1% level of significance. Hence, the hypothesis of equality of mean treatment effect is rejected. This implies that at least one of the mean treatment effects is significantly different from the others. The Partial Eta Square (PES) statistics report the 'practical' significance of each process condition. Larger values of PES indicate a more significant amount of variation accounted for by the model process conditions to a maximum of 1. The closer the value of PES of process condition is to 1, the higher the contribution or effect of such term to the significance of the model [25]. Hence, it can be concluded from Table 7 that temperature, drying method, drying rate, and their interactions contributed strongly to the significance of water losses of the onion samples. The result of comparison among the three levels of temperature revealed that at any particular drying temperature, the practical means of drying rate are significantly different from each other for all the onion varieties studied. This implies that onions dried at 50ºC are statistically different from those dried at 60ºC, 70ºC, or vice versa.

3.4 Effect of Drying Time on Drying Rate at Various Drying Conditions

Drying rates at different levels of drying duration are significantly different from each other. The drying rate and moisture content decreased continuously with drying time in the three drying methods. A higher rate of moisture removal was observed in both kerosene and electrically powered dryers for all drying samples at the initial drying stage than in the later stages. This characteristics behaviour is due to various forms in which water is present in food products. From the curves shown (Figs. 1 to 6), there was no constant drying period in the entire process. All drying processes occurred in a falling rate. During the falling rate period, the drying process of onion was mainly controlled by diffusion mechanisms. In the initial, stage moisture migrations from the surface are faster and quickly evaporated. As the drying progressed, the rate dropped due to internal moisture diffusion resulting in a falling rate. However, the thickness of the onion did not present a serious barrier. This is in agreement with earlier research works by Brewster and Rabinowitch [26], Lee et al. [22], and Markowski [12].

Table 5. ANOVA for final drying rate of onions

		Sum of Squares	df	Mean Square	F	Sig.
Drying Method	Between Groups	29.024	54	.537	2.345	.100
	Within Groups	1.833	8	.229		
	Total	30.857	62			
Temperature (0)	Between Groups	5850.142	54	108.336	5.200	.009
	Within Groups	166.667	8	20.833		
	Total	6016.809	62			
Time (Hrs)	Between Groups |	1350.317	54	25.006	6.124	.005
	Within Groups	32.667	8	4.083		
	Total	1382.984	62			
Percentage Water Loss (%)	Between Groups	188.788	54	3.496	65.551	.000
	Within Groups	.427	8	053		
	Total	189.2414	62			
Percentage Final Moisture Content (%)	Between Groups	414.108	54	2.113	39.621	.000
	Within Groups	.427	8	053		
	Total	114.534	62			
Drying Rate (g/hr)	Between Groups	64873.444	54	1201.360	1.786	.194
	Within Groups	5382.095	8	672.762		
	Total	70255.539	62			

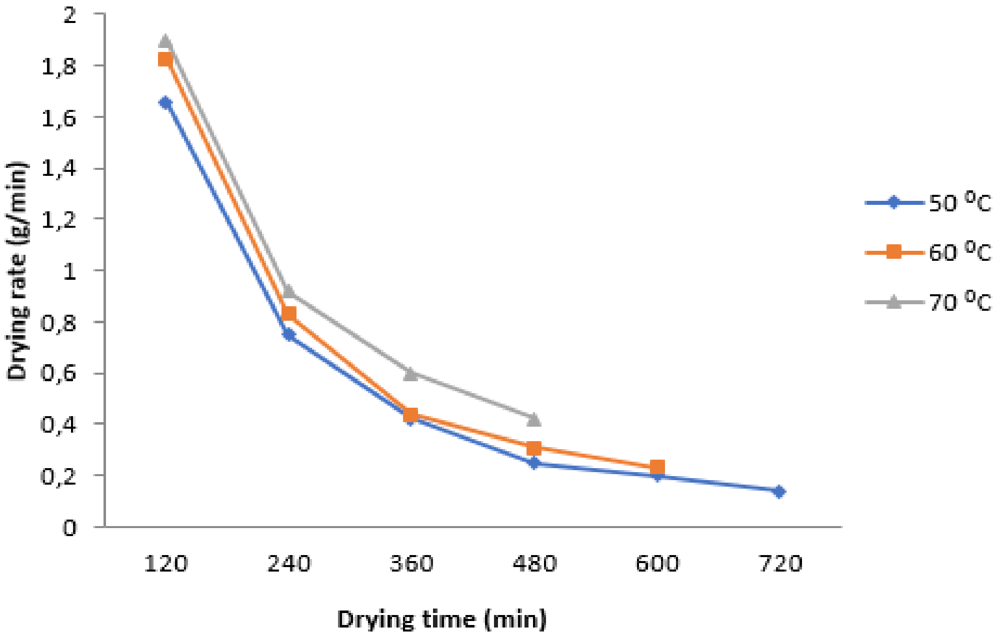

Fig. 1. Drying rate curve for red onion using electric dryer

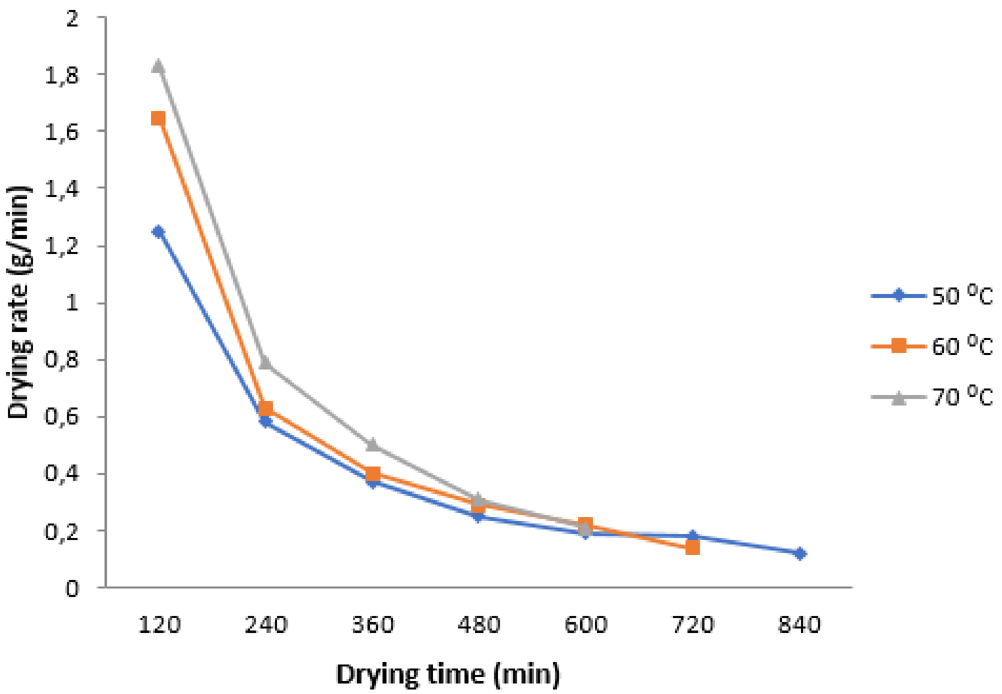

Fig. 2. Drying rate curve for white onion using electric dryer

3.5 Effect of Drying Temperature on Drying Rate at Various Drying Conditions

The graphs of drying temperatures versus drying rate curves (Figs. 7 – 9) revealed that a higher drying rate was observed at higher temperature (70ºC) irrespective of the onion varieties in both kerosene and electrically powered drying considered for the experiment. This is because as air temperature increases, the drying air can heat up the product, move over the product, and provide latent heat for moisture evaporation, thereby increasing the driving force for drying. Several authors reported considerable increases in drying rates when higher temperatures were used for drying various fruits, vegetables, and crops [27,16,17].

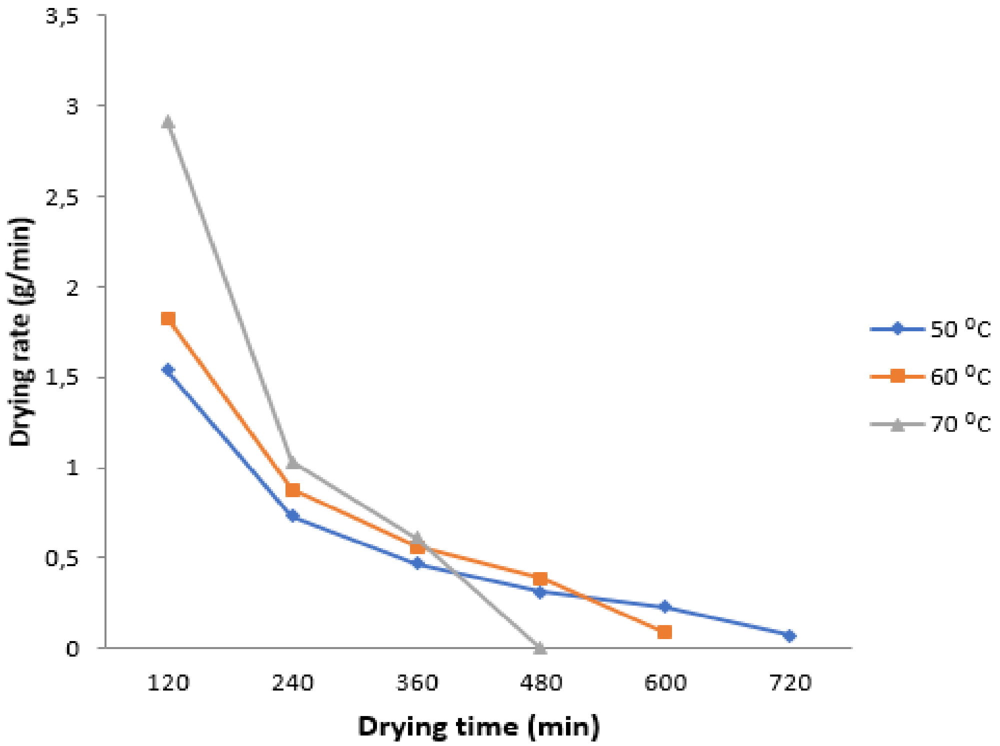

Fig. 3. Drying rate curve for cream onion using electric dryer

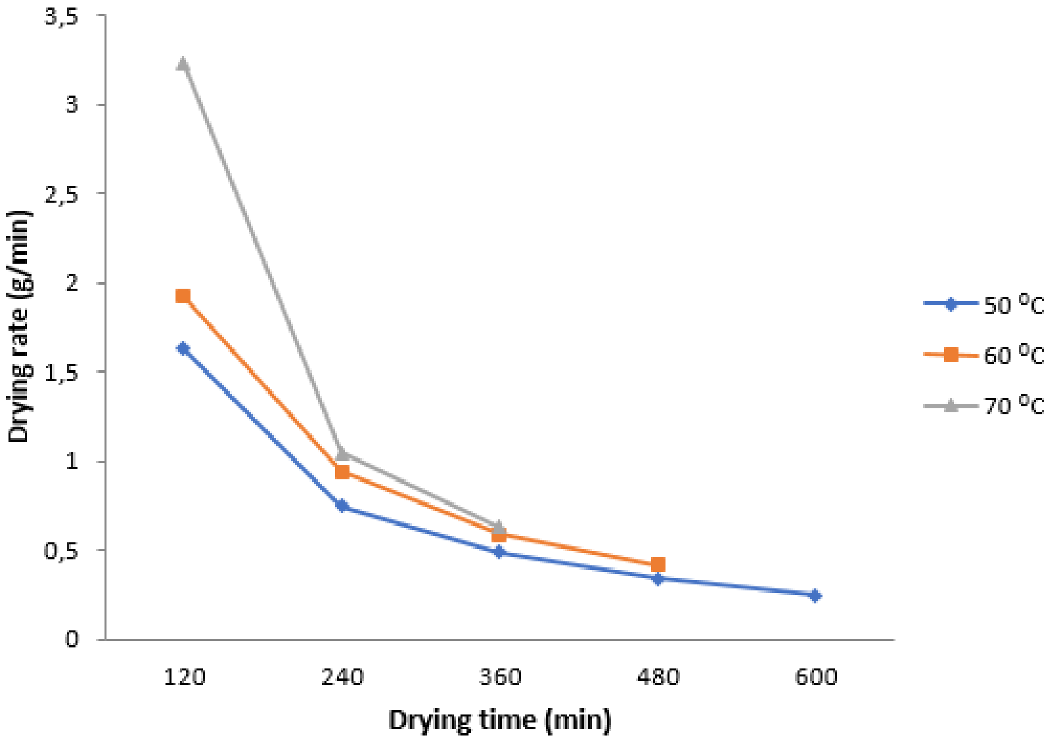

Fig. 4. Drying rate curve for red onion using kerosene dryer

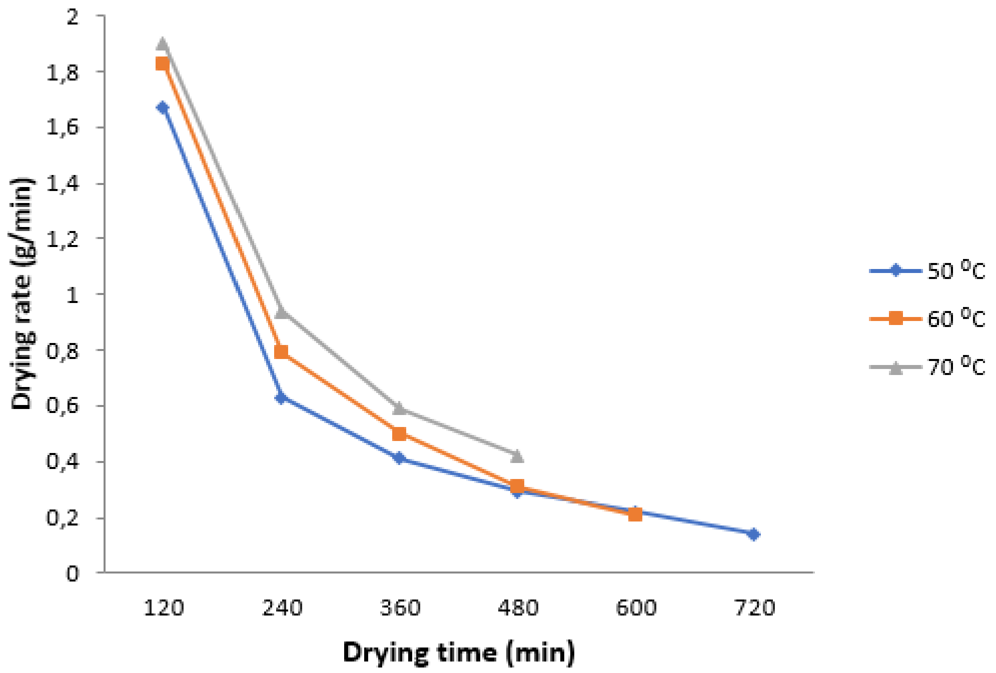

Fig. 5. Drying rate curve for white onion using kerosene dryer

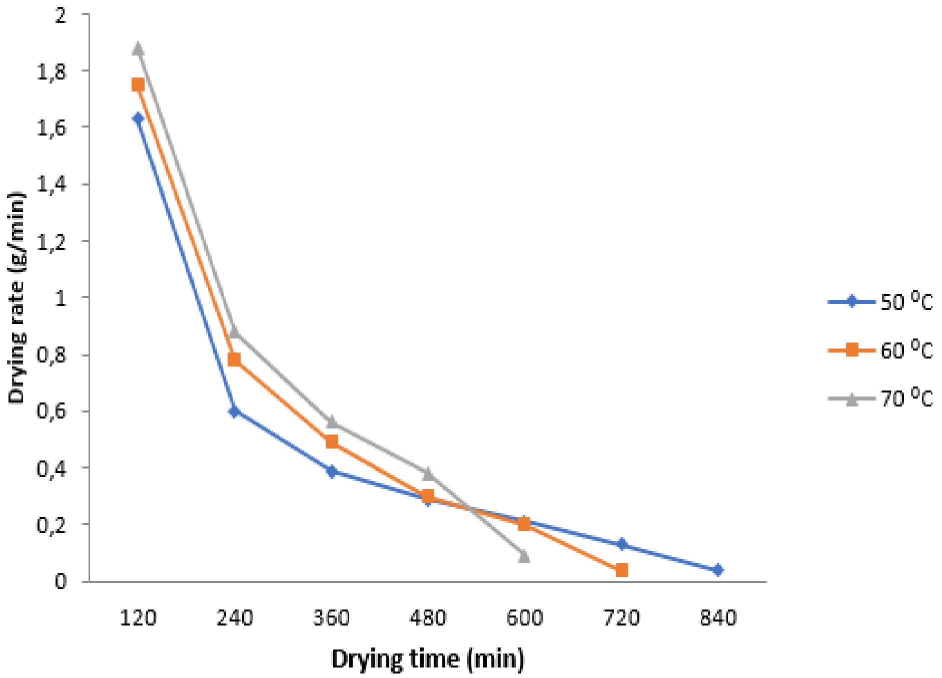

Fig. 6. Drying rate curve for cream onion using kerosene dryer

3.6 Effect of Drying Methods on the Drying Rate of the Three Onion Varieties

Figs. 10 to 12 show the drying methods' effects on the drying rate as they occurred during the the drying process. The drying rate increased with the increase in the drying temperatures in kerosene and electric drying, except the solar drying that was carried out at a drying temperature of 50ºC. The highest drying rate is seen with an electrically powered dryer in drying red and cream onions. This might be due to the quick time of the heat emitters of the dryer in attaining the pre-determined temperatures in the shortest time and the air movement within the system. The drying rate has a direct relationship with the air temperature; this interaction is consistent with the reports of Rahman and Petera [19], Akbari and Patel [23], and Schiffman [24].

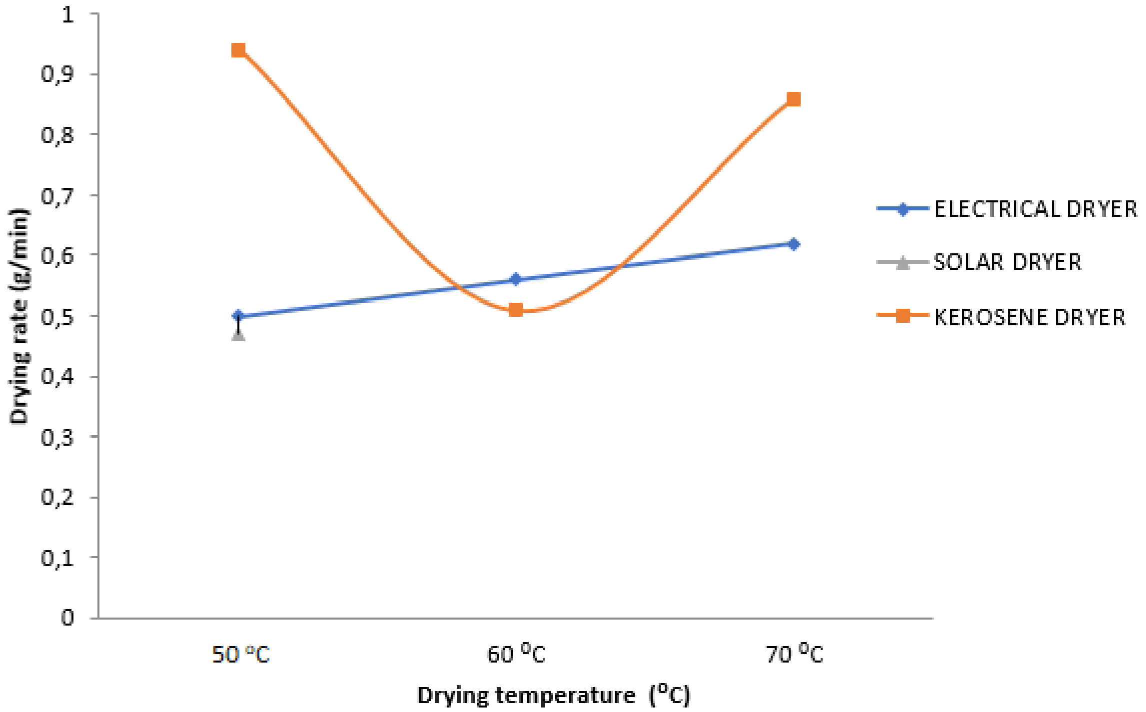

Fig. 7. Effects of drying temperatures on drying rate of red onion at various drying methods

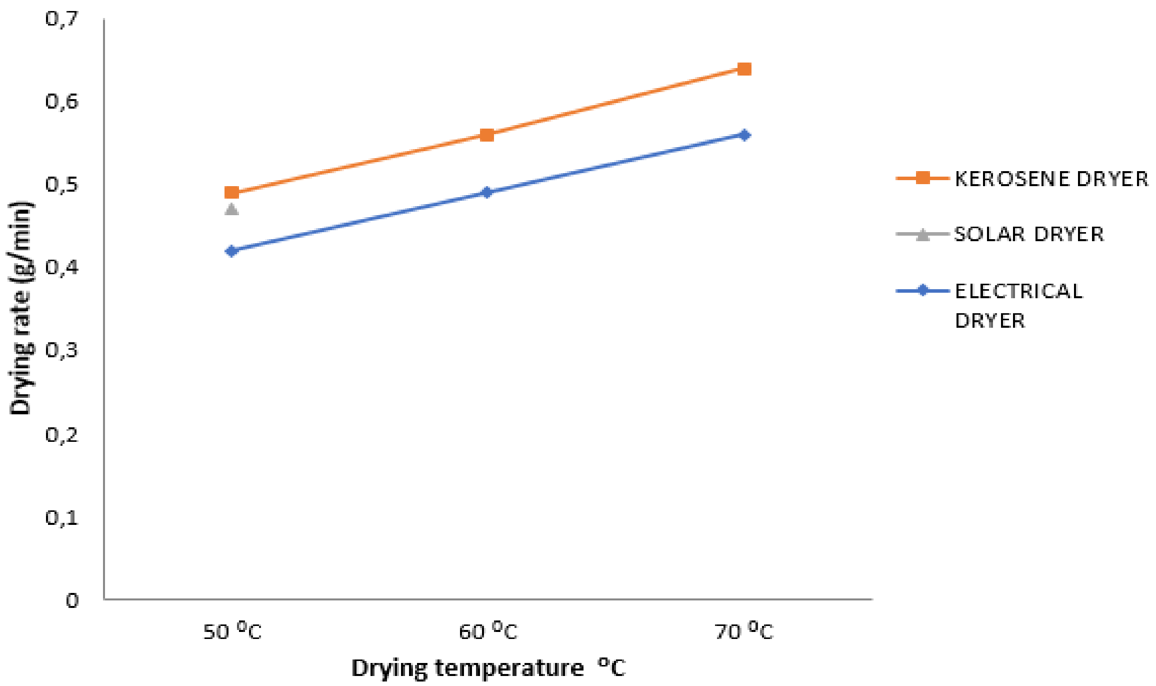

Fig. 8. Effects of drying temperatures on drying rate of white onion various drying methods

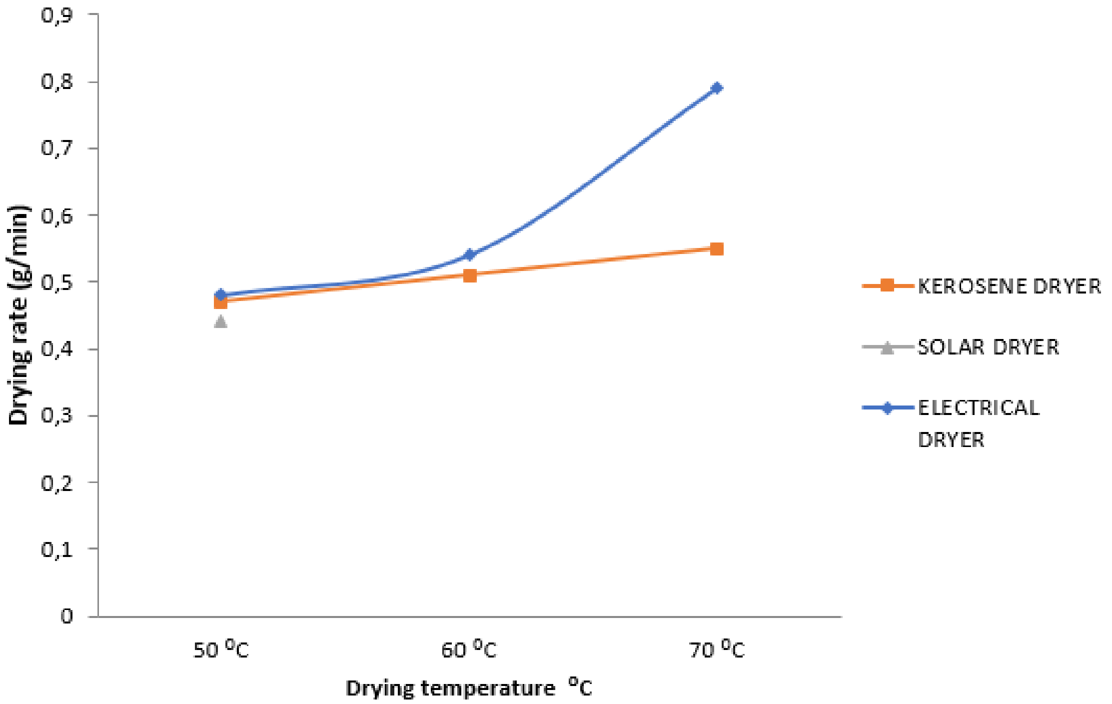

Fig. 9. Effects of drying temperatures on drying rate of cream onion at various drying methods

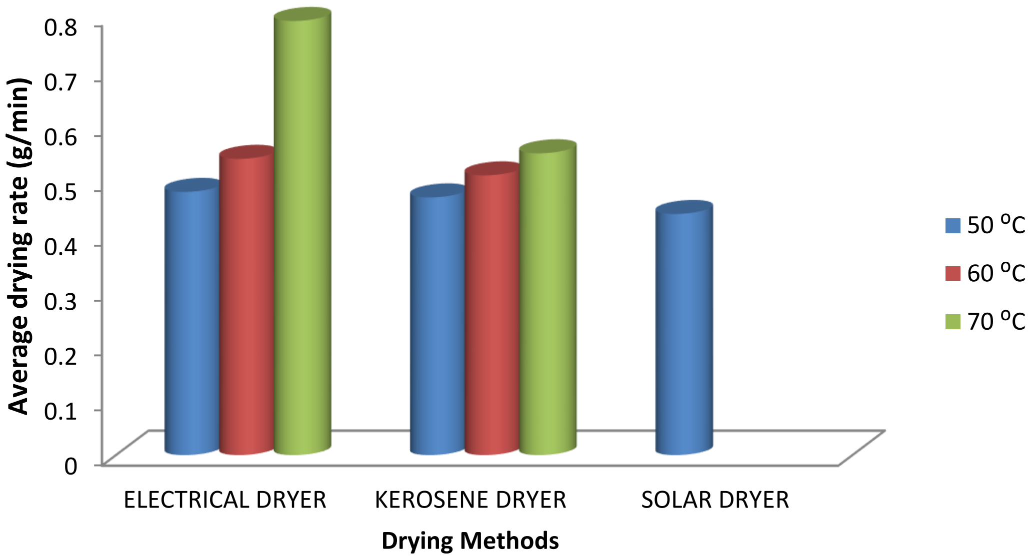

Fig. 10. Effects of drying methods on red onion

3.7 Effects of Drying Methods on Pungency for all the Drying Trials

The changes in pyruvate levels at the end of the drying process are shown in Fig. 13 – 19. Pungency changes caused by drying had similar trends for red, white, and cream onion samples dried using both electrical and kerosene drying methods but a slight difference occurred in pieces dried with the solar process. Although the measured pungencies varied with drying conditions and moisture during drying, the pungencies in the final samples with similar moisture content were identical, except for the 70

°C trials. All the onion varieties with 70°C trial showed a more significant loss in pungency in the samples dried in the electric and kerosene drying, especially near the end of drying. This may be due to the high drying temperature that was used in drying. For all the electric and kerosene dried samples, the pungency changes had a similar trend.

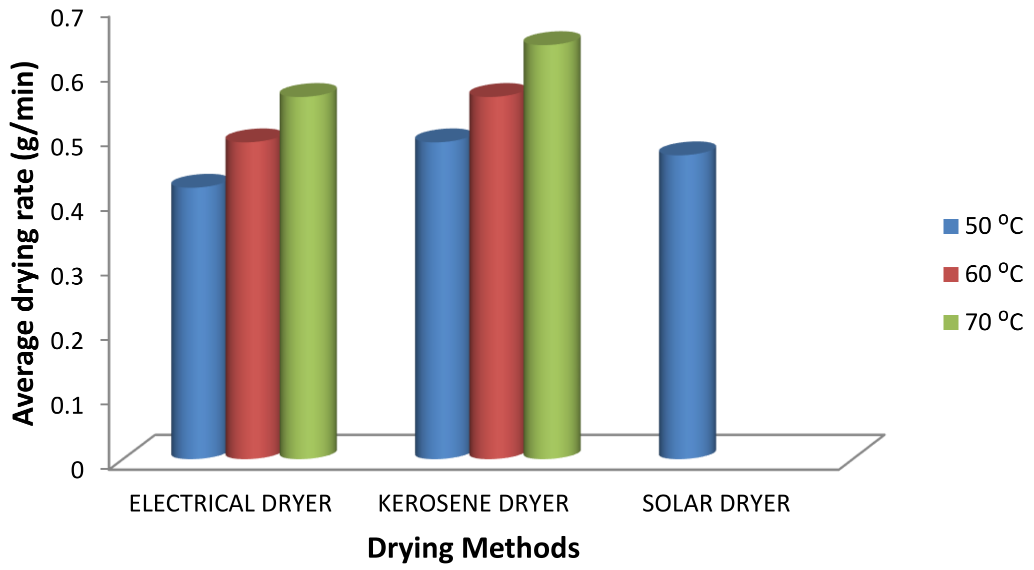

Fig. 11. Effects of drying methods on white onion

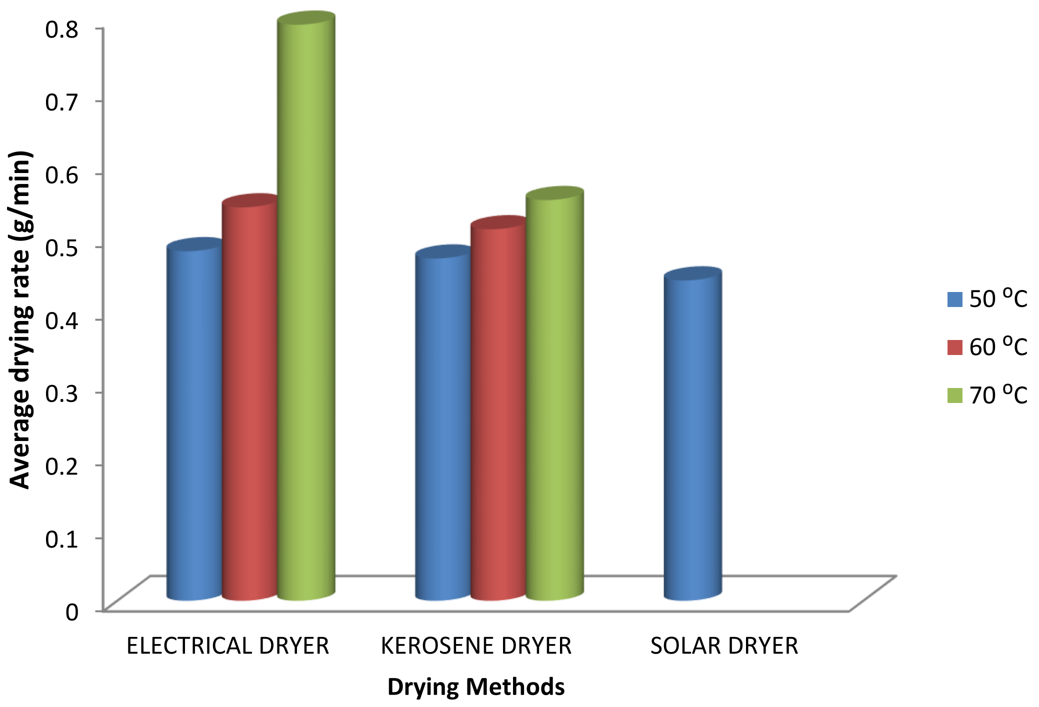

Fig. 12. Effects of drying methods on cream onion

There was no significant differences in the pungency loss between the electrical and kerosene dried products at 50°C. Furthermore, samples dried at 60 °C for both drying methods had similar pyruvate levels at the end of drying. This is consistent with the finding of Sharma and Nath [15]. Additional studies [28,26,22] have shown that accelerated drying in the initial stages would retain volatiles. The volatiles becomes "locked" into the product when it reaches the critical moisture content. For solar drying, the final pungency values decreased with the drying temperatures for the period of drying. This might be as a result of the more extended drying period leading to the escape of the volatiles.

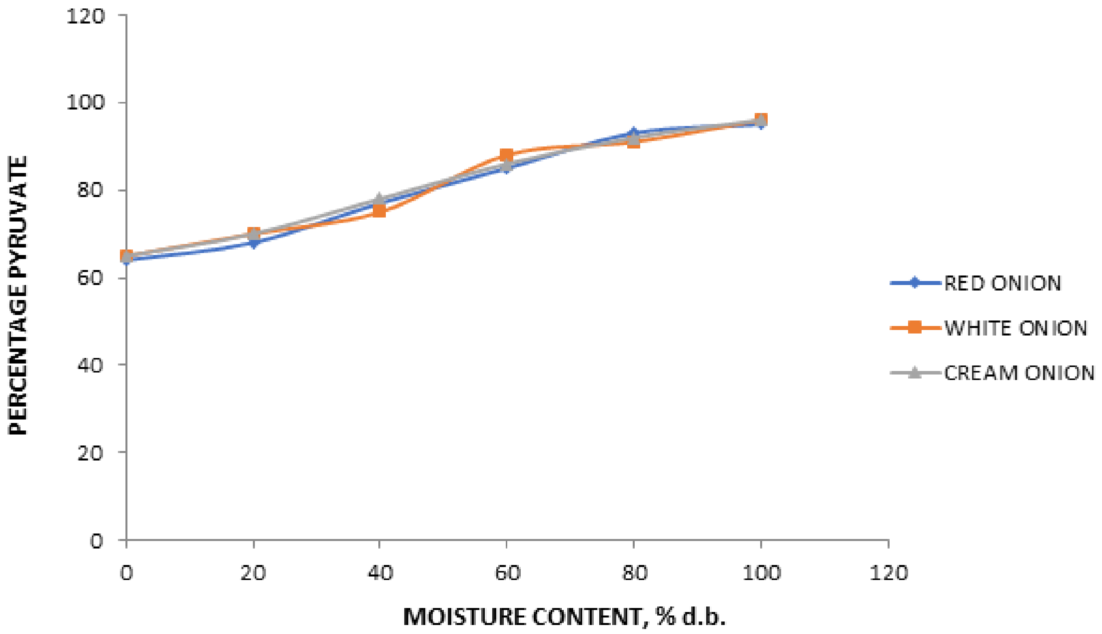

Fig. 13. Electric drying of onions at 50°C

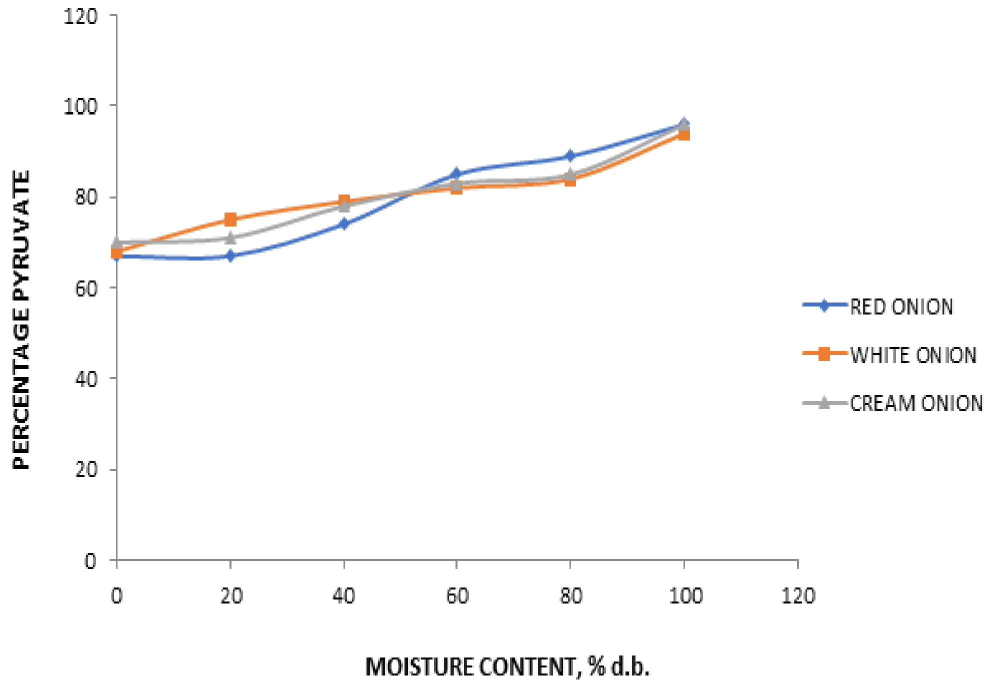

Fig. 14. Electric drying of onions at 60°C

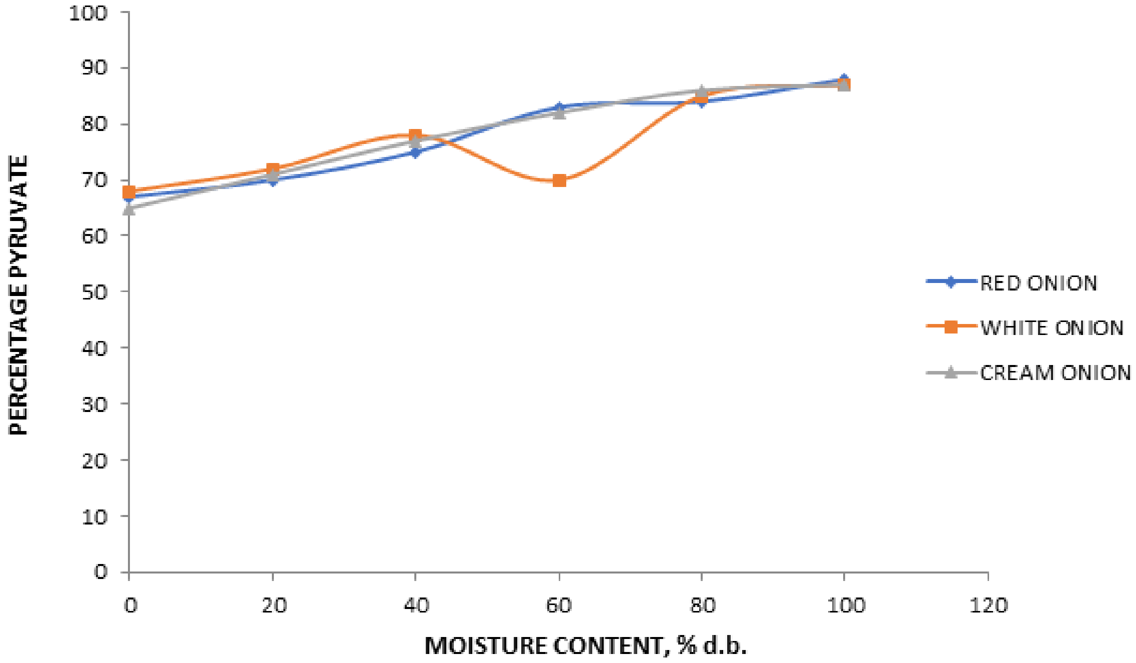

Fig. 15. Electric drying of onions at 70ºC

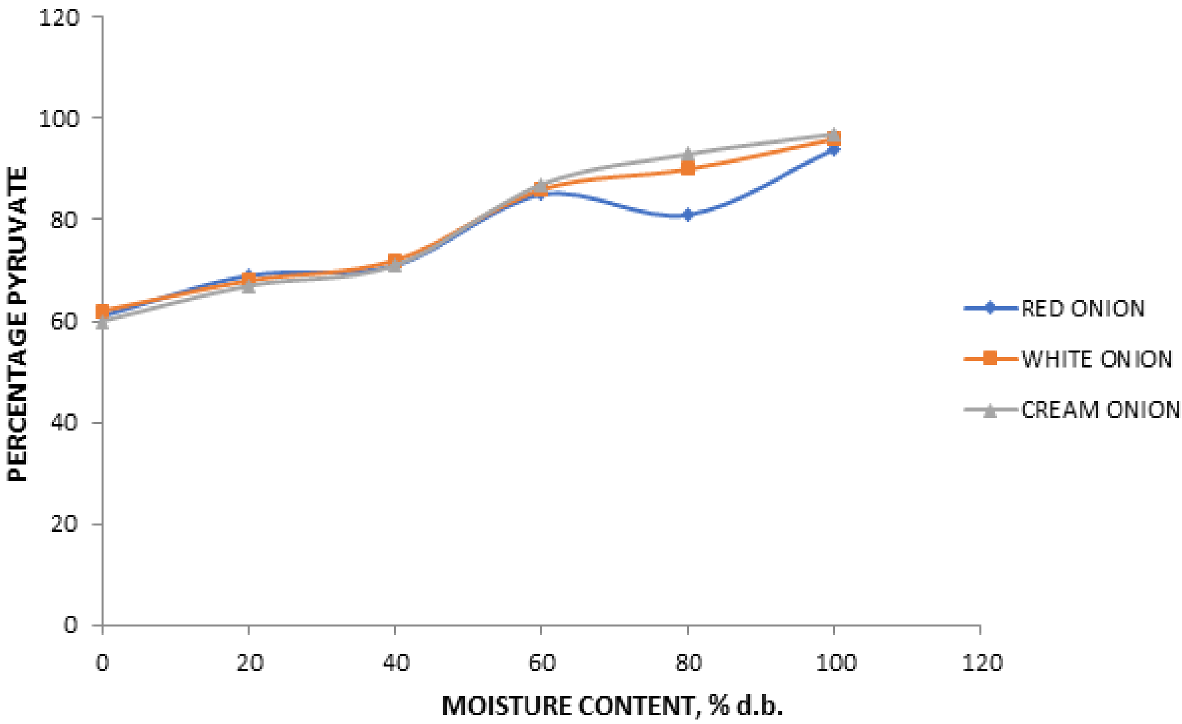

Fig. 16. Kerosene drying of onions at 50ºC

3.8 Effects of Drying on Microbial load for all the Drying Trials

The microbial counts from individual experiments of red, white, and cream onions are summarized in Tables 6, 7, and 8. There were no differences in microbial counts using the three drying methods at different drying temperatures. The final counts were composed primarily of aerobic spore formers. According to Matron [29], these are the predominant microorganisms in dehydrated species. Spore-forming bacteria are likely to survive the drying process because they can survive in a high heat environment. The increased survival of the aerobic spore formers and inactivation of other populations of microorganisms would account for similar final counts. The population that were reduced were most likely vegetative cells, of which include coliforms.

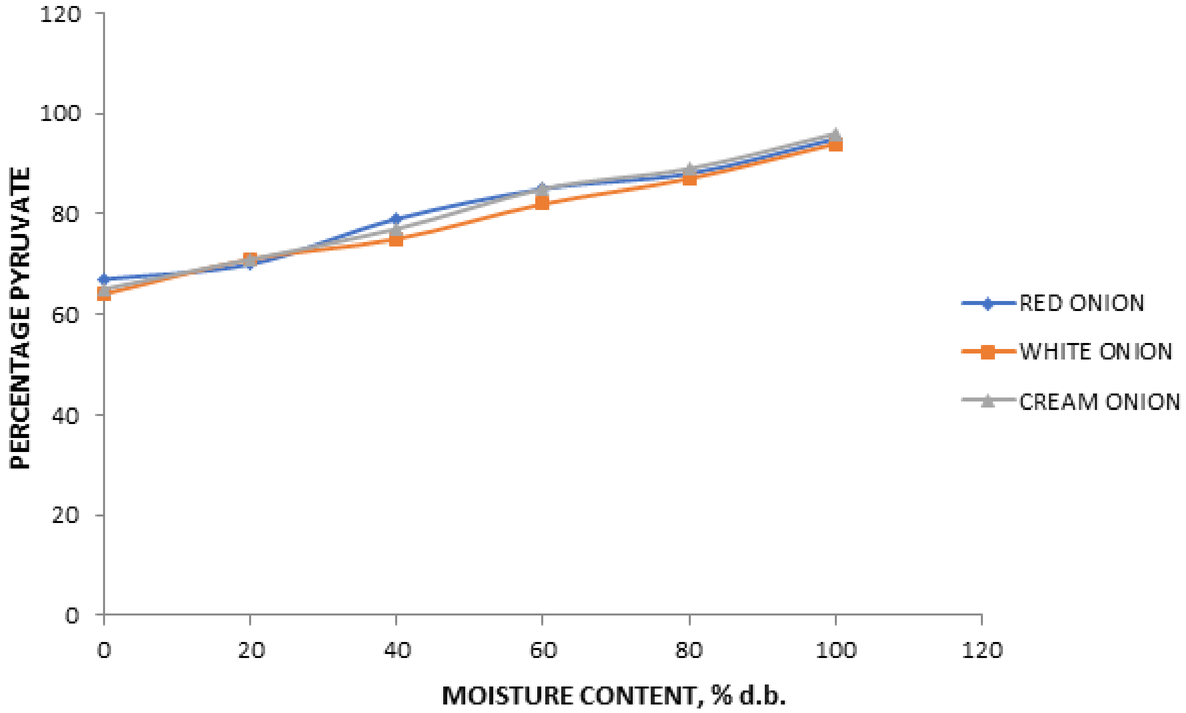

Fig. 17. Kerosene drying of onions at 60°C

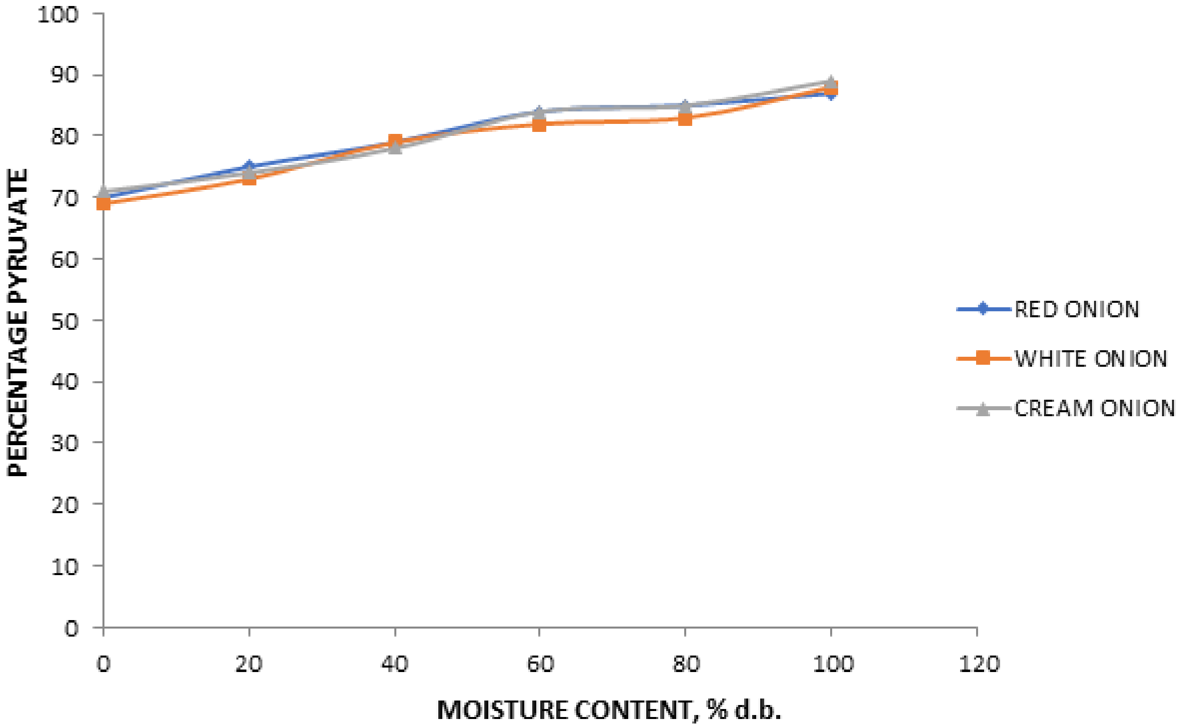

Fig. 18. Kerosene drying of onions at 70°C

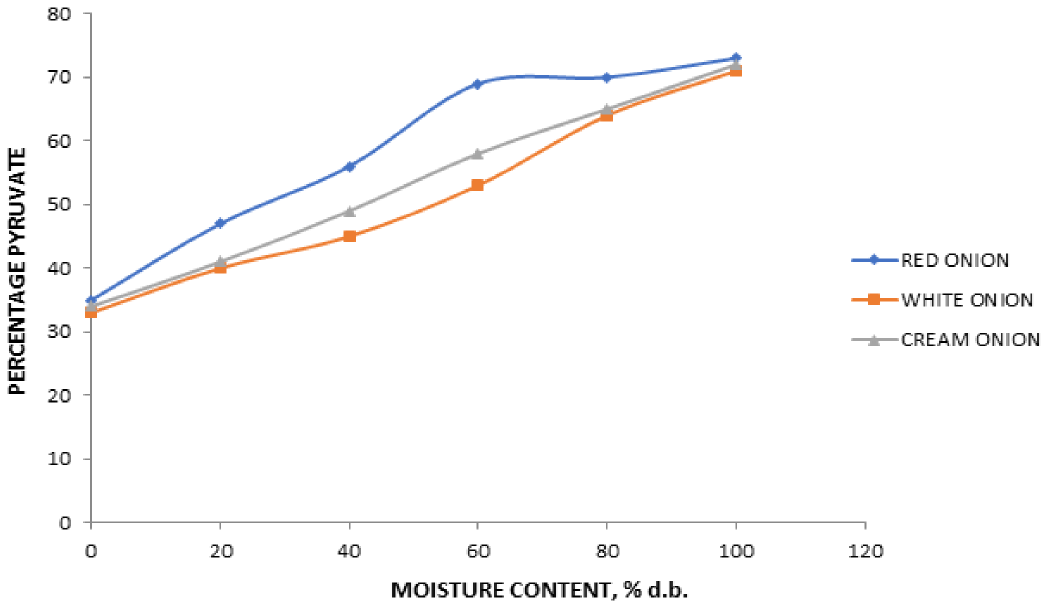

Fig. 19. Solar drying of onions at 50°C

Yeast and mold counts, unlike coliform, were not accounted for on the APC. Yeasts and molds do not grow fast enough to appear on APC agar. In the experiments, yeast and mold counts were significantly different for the three drying methods, with greater reductions in sample dried in the electric dryer. More significant reductions in the electrical powered dryer were probably a result of greater heat fluxes from the electric emitter. This is consistent with the other research work reported by Kornacki and Johnson [30]. For the yeast and mold count, the dried samples had greater counts than the fresh samples. This might result from replicating organisms after drying, although properly dried products should be free of microbial multiplication. Another reason could be that fresh onions contained antimicrobial action and allowed for more accurate microbial counts, as reported by Rahaman and Perera, [15].

Table 6. Aerobic plate, yeast and mould counts of electrical, kerosene and solar dried samples for red onions

Aerobic Plate Counts	Trail 1				Trail 2				Average			
	Fresh	5.24			Fresh	5.24			Fresh	5.24		
		E	K	S		E	K	S		E	K	S
Dried	50 °C	4.21	4.08	4.06	50 °C	3.23	3.41	3.52	50°C	3.72	3.75	3.79
	60 °C	3.98	4.05		60 °C	3.71	3.36		60°C	3.85	3.71	
	70 °C	3.97	4.03		70 °C	3.37	3.39		70°C	3.67	3.71	
Coliform Counts	**Trail 1**				**Trail 2**				**Average**			
	Fresh	5.27			Fresh	5.51			Fresh	5.39		
		E	K	S		E	K	S		E	K	S
Dried	50 °C	3.04	3.95	3.78	50 °C	2.40	2.40	2.21	50 °C	2.72	3.18	2.99
	60 °C	2.18	3.93		60 °C	2.40	2.18		60 °C	2.29	3.06	
	70 °C	1.70	3.00		70 °C	1.00	1.00		70 °C	1.35	2.00	
Yeast and Mold Counts	**Trail 1**				**Trail 2**				**Average**			
	Fresh	4.56			Fresh	4.84			Fresh	4.70		
		E	K	S		E	K	S		E	K	S
Dried	50 °C	4.16	4.72	4.83	50 °C	4.12	4.81	4.90	50 °C	4.14	4.77	4.87
	60 °C	3.83	4.69		60 °C	4.00	4.31		60 °C	3.92	4.50	
	70 °C	3.44	4.10		70 °C	3.44	4.00		70 °C	3.44	4.05	

Where E = Electric; K = Kerosene; S = Solar

Table 7. Aerobic plate, yeast and mould counts of electrical, kerosene and solar dried samples for white onions

Aerobic Plate		Trail 1				Trail 2				Average		
Counts	Fresh	5.31			Fresh	5.31			Fresh	5.31		
		E	K	S		E	K	S		E	K	S
	50 ºC	4.21	4.04	4.01	50 ºC	3.23	3.51	3.04	50 ºC	3.72	3.78	3.53
Dried	60 ºC	3.98	4.02		60 ºC	3.51	3.36		60 ºC	3.75	3.69	
	70 ºC	3.97	4.03		70 ºC	3.37	3.39		70 ºC	3.67	3.71	
Coliform		Trail 1				Trail 2				Average		
Counts	Fresh	5.24			Fresh	5.41			Fresh	5.32		
		E	K	S		E	K	S		E	K	S
	50 ºC	3.04	3.75	3.28	50 ºC	2.40	2.40	2.24	50 ºC	2.72	3.08	2.76
Dried	60 ºC	2.18	3.53		60 ºC	2.45	2.28		60 ºC	2.32	2.91	
	70 ºC	1.70	3.00		70 ºC	1.00	1.00		70 ºC	1.35	2.00	
Yeast and Mold		Trail 1				Trail 2				Average		
Counts	Fresh	4.55			Fresh	4.64			Fresh	4.60		
		E	K	S		E	K	S		E	K	S
	50 ºC	4.36	4.62	4.43	50 ºC	4.15	4.61	4.40	50 ºC	4.26	4.62	4.42
Dried	60 ºC	3.63	4.61		60 ºC	4.01	4.41		60 ºC	3.82	4.51	
	70 ºC	3.54	4.13		70 ºC	3.04	4.05		70 ºC	3.29	4.09	

Where E = Electric; K = Kerosene; S = Solar

Table 8. Aerobic plate, yeast and mould counts of electrical, kerosene and solar dried samples for cream onions

		Trail 1				Trail 2				Average		
	Fresh	5.27			Fresh	5.26			Fresh	5.27		
Aerobic Plate		E	K	S		E	K	S		E	K	S
Counts	50 ºC	4.31	4.18	4.16	50 ºC	3.33	3.41	3.21	50 ºC	3.82	3.80	3.69
	60 ºC	3.68	4.15		60 ºC	3.51	3.34		60 ºC	3.60	3.75	
	70 ºC	3.77	4.13		70 ºC	3.27	3.49		70 ºC	3.52	3.81	
		Trail 1				Trail 2				Average		
	Fresh	5.24			Fresh	5.51			Fresh	5.38		
Coliform		E	K	S		E	K	S		E	K	S
Counts	50 ºC	3.14	3.75	3.53	50 ºC	2.30	2.30	2.01	50 ºC	2.72	3.03	2.77
	60 ºC	2.38	3.83		60 ºC	2.50	2.28		60 ºC	2.44	3.06	
	70 ºC	1.40	3.10		70 ºC	1.10	1.00		70 ºC	1.25	2.00	
		Trail 1				Trail 2				Average		
	Fresh	4.36			Fresh	4.54			Fresh	4.45		
Yeast and Mold		E	K	S		E	K	S		E	K	S
Counts	50 ºC	4.26	4.62	4.61	50 ºC	4.22	4.81	4.60	50 ºC	4.24	4.72	4.61
	60 ºC	3.53	4.59		60 ºC	4.10	4.21		60 ºC	3.82	4.40	
	70 ºC	3.34	4.20		70 ºC	3.34	4.10		70 ºC	3.34	4.15	

Where E = Electric; K = Kerosene; S = Solar

Generally, aerobic plate counts (APC) had similar results for the samples dried with the three drying methods at the three temperatures. Coliform counts were similar for the three drying methods, but the counts decreased as drying temperature increased in electric and kerosene drying. The yeast and mold counts were lower for the electric dried samples than those dried with the kerosene and solar. There was also a decrease in the yeast and mold as the drying temperature increased for electric and kerosene drying methods.

Table 9. Sensory evaluation mean scores of the onion samples dried with electric dryer

Samples	Appearance	Colour	Flavour	Aroma	Taste	Acceptance
Electric (Red)						
50^0C	5.73± 2.12[a]	5.52± 2.13[a]	4.88±0.42[a]	5.93±0.31[a]	5.64±0.04[a]	5.02± 1.21[a]
60^0C	6.47± 1.50[b]	6.72± 1.11[b]	6.23±0.39[b]	6.22±0.51[b]	6.01±0.08[b]	6.00± 1.59[b]
70^0C	7.11± 0.13[c]	7.75± 1.13[c]	7.47±0.67[c]	7.56±1.31[c]	7.47±0.12[c]	7.01± 1.38[c]
White						
50^0C	5.72± 0.11[a]	6.41± 1.12[a]	5.04±0.24[a]	5.06±0.21[a]	4.96±0.02[a]	5.22± 0.92[a]
60^0C	6.04± 2.14[b]	6.22± 1.05[b]	5.87±0.83[b]	6.94±0.91[b]	5.94±0.10[b]	6.02± 2.03[b]
70^0C	7.42± 1.13[c]	7.71± 1.10[c]	6.95±1.25[c]	7.63±3.41[c]	7.12±0.16[c]	6.92± 1.53[c]
Cream						
50^0C	5.53± 0.14[a]	6.52± 1.03[a]	4.53±0.26[a]	5.11±0.31[a]	4.67±0.20[a]	5.42± 1.13[a]
60^0C	6.54± 1.51[b]	6.42± 1.13[a]	6.15±0.16[b]	6.31±0.21[b]	5.27±0.09[b]	6.62± 1.17[b]
70^0C	7.52± 1.13[c]	7.74± 1.10[b]	7.52±0.94[c]	7.53±0.41[c]	7.17±0.26[c]	7.02± 0.15[c]
Mean	7.55	7.99	6.64	6.70	6.20	7.37
SD	0.9179	0.6563	1.3788	1.9559	1.1462	0.8957

Higher value indicates greater preference. Values are Means ± SD (n=20)
Column with different superscripts are significantly different at p<0.05

Table 10. Sensory evaluation mean scores of the onion samples dried with kerosene dryer

Samples	Appearance	Colour	Flavour	Aroma	Taste	Acceptance
Kerosene(Red)						
50ºC	5.51± 1.13[a]	5.72± 0.14[a]	4.88±0.42[a]	4.93±0.31[a]	4.94±0.04[a]	4.70± 2.03[a]
60ºC	6.02± 1.13[b]	6.32± 2.13[b]	5.23±0.39[b]	5.32±0.51[b]	6.01±0.08[b]	6.32± 1.10[b]
70ºC	7.32± 0.13[c]	7.12± 1.13[c]	7.47±0.67[c]	7.46±1.31[c]	7.07±0.12[c]	7.52± 2.03[c]
White						
50ºC	5.02± 0.13[a]	5.12± 1.12[a]	5.04±0.24[a]	5.06±0.21[a]	4.96±0.02[a]	5.01± 1.20[a]
60ºC	6.72± 1.13[b]	6.72± 1.11[b]	5.07±0.83[a]	5.94±0.91[a]	5.94±0.10[b]	6.54± 1.52[b]
70ºC	7.19± 0.17[c]	7.12± 1.03[b]	6.85±1.25[c]	7.23±3.41[b]	7.12±0.16[c]	7.72± 1.17[c]
Cream						
50ºC	5.12± 0.13[a]	6.22± 1.12[a]	4.23±0.26[a]	4.61±0.31[a]	4.37±0.22[a]	4.62± 1.86[a]
60ºC	6.72± 1.00[b]	6.52± 1.20[a]	5.45±0.16[b]	5.31±0.21[b]	5.27±0.09[b]	6.02± 1.03[b]
70ºC	7.32± 1.11[c]	7.02± 1.11[b]	6.92±0.94[c]	7.23±0.41[c]	7.17±0.26[c]	7.42± 1.23[c]
Mean	7.00	7.55	6.24	6.44	5.99	7.67
SD	0.9654	0.9165	1.3346	1.9679	1.1018	1.2596

Higher value indicates greater preference. Values are Means ± SD (n=20)
Column with different superscripts are significantly different at p<0.05

Table 11. Sensory evaluation mean scores of the onion samples dried with solar dryer

Samples	Appearance	Colour	Flavour	Aroma	Taste	Acceptance
Solar (Red)						
50 ºC	3.12± 2.13[a]	4.72± 1.03[a]	3.23±0.26[a]	3.11±0.31[a]	3.37±0.22[a]	4.62± 0.11[a]
White						
50 ºC	3.70± 1.03[a]	4.01± 0.13[a]	3.45±0.16[a]	3.31±0.21[a]	3.27±0.09[a]	4.42± 0.13[a]
Cream						
50 ºC	3.52± 1.13[a]	4.13± 1.10[a]	3.82±0.94[a]	3.53±0.41[a]	3.17±0.26[a]	4.52± 0.15[a]
Mean	4.84	5.04	3.95	3.62	4.57	4.65
SD	0.2686	0.8216	0.7023	0.2809	1.9235	0.0837

Higher value indicates greater preference. Values are Means ± SD (n=20)
Column with different superscripts are significantly different at p<0.05

3.9 Effects of Drying Methods on Sensory Properties of Dried Samples

The results of the mean score of the sensory evaluation studies on the effects of the three drying methods on the dried onions are presented in Tables 9 – 11. Samples of red, white, and cream onions were dried at 50 ºC, 60 ºC, and 70 ºC with solar, kerosene, and electrically powered dryers. In these studies, the consideration was on the drying methods and drying temperatures. The appearance of the sun-dried samples was not acceptable to the commercial users of onion due to the blackish colour. The only way to identify the sample was a close perception of the onion flavour. The attendant issue of contaminations with dust and insects on the samples could not be controlled.

The sensory evaluation revealed that dried onions at 70 ºC with kerosene and electrically powered dryers were most preferred in appearance, color, taste, flavor, aroma, and overall acceptability than other dried onions at 50 ºC and 60 ºC with solar, kerosene, and electrically powered dryers. These results might be due to high temperature cumulating to shorter time in drying, which disallows browning of onion and retention of pungency. Dried onions at 50 ºC with solar, kerosene, and electrically powered dryers were least preferred in appearance, taste, aroma, and overall acceptability. Tables 9 and 10 show that in kerosene and electrically powered dryers, all the sensory parameters investigated on dried onions dried at 70ºC were not significantly affected by the drying temperature or drying methods. Also, it was observed that dried onions at 50ºC with solar, kerosene, and electrically powered dryers had significant effects on all the sensory parameters investigated on the dried onions.

3.10 Sun Drying of Red, White, and Cream Onion (Control Experiment)

The onion samples from each variety were sun-dried for 144 h to attain average moisture content of 24.54%. Due to the hygroscopic nature of all drying food, reabsorption of moisture was inevitable in all the drying samples, which allowed the samples to go mouldy. Consequently, the samples turned blackish at the end of the drying process. The appearance of the sun-dried samples was not acceptable to the commercial users of onion due to the blackish colour. The only way to identify the sample was a close perception of the onion flavour. The attendant issue of contaminations with dust and insects on the samples could not be controlled.

4. CONCLUSION

The effects of some drying methods on the qualities of dried Nigerian onion varieties has been studied. The use of kerosene, solar, and electrically powered dryers significantly affected onion constituents and flavor. A higher drying rate can be obtained with the electric dryer, resulting in a faster drying process. The electric dryer was able to attain the required temperature quickly and further maintained the temperature, which proved to be the best method for drying the onions at 70 ºC. The drying temperatures of all dryers used resulted in pungency degradation of the dried onion samples compared with the fresh samples. There was more excellent pungency retention at 70 ºC in both kerosene and electrically powered dryers. The electric dryer is efficient in producing safely dried onion as it produced products with reduced microbial load accompanied by reduced moisture content. Dried onions at 70 ºC with kerosene and electrically powered dryers were most preferred in appearance, color, taste, flavor, aroma, and overall acceptability than other dried onions at 50 and 60 ºC. The overall cost-benefit analysis showed that the solar dryer is more profitable for drying onions as it yielded more returns, followed by the electric dryer.

DISCLAIMER

The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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