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Effect of Drying Methods on the Moisture Content and Microbiological Properties of Three Varieties of Dried Onion Slices (*Allium cepa*).

Aremu, M. B*., Adeiza, O. A., Rahman, O. M., Kurrah, I. A., Oyewopo, A. O., Olaleye, O. O. and Akande, S.A.

Nigeria Stored Products Research Institute, Km 3, Asa Dam Road, Ilorin, Kwara State, Nigeria.

***Corresponding authors**
Aremu Mariam Bukola,
Nigerian Stored Products Research Institute,
Km 3 Asa Dam Road,
P.M.B. 1489,
Ilorin, Kwara State,
Nigeria.

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Abstract

Post-Harvest losses of onions occurring due to poor handlings and spoilage by microorganisms is worthy of concern. Value addition through drying during peak seasons can reduce losses remarkably. This study sought to evaluate the effects of different drying methods on the microbial load of dried onion slices. Three varieties of onion (red, white and cream) were purchased National Institute for Horticultural Research (NIHORT) Kano sub-station and processed into dried slices using three dryers namely; Solar Cabinet Dryer (SCD), Electric Powered Dryer (EPD) and Kerosene Powered Dryer (KPD) at three different temperatures (50, 60 and 70°C). The dried onion slices were then evaluated for their microbial load; Aerobic Plate Counts (APC), Coliform Counts (CC) and Fungal Counts (FC) using three different media and according to standard methods. The results revealed that MC of onions were reduced from 88.29% to as low as 5.19% during drying. The APC, CC and FC of red onion ranged from 3.67–5.39×10² cfu/g, 1.35–5.39×10² cfu/g and 3.44–4.83×10² cfu/g respectively. The load for white onion ranged from 3.11–5.19×10² cfu/g, 1.31–5.29×10² cfu/g and 3.43–4.53×10² cfu/g respectively while that of cream onion ranged from 3.30–5.33×10² cfu/g, 1.33–5.39×10² cfu/g and 3.42–4.57×10² cfu/g respectively. All the readings fell below the international recommended safe limit for food consumption. The EPD samples at 60°C and 70°C had the significant lowest ($p \leq 0.05$) fungal counts in all the onion varieties. Therefore, electric oven dryer at 70°C was the best drying methods and temperature for onion for long time storage.

Keywords : Post-Harvest loss, Onions, dehydration, value-addition, food safety

Introduction

Onion (*Allium cepa L*) is a vegetable crop grown in almost all over the world (Manna, 2014). It is grown mainly for its bulb, which is used in every home almost daily. It is by far the most important of the bulbs cultivated commercially in nearly most parts of the world (Berhanu & Berhanu, 2014). As an important food, the immature and mature bulbs are eaten raw or they may be cooked and eaten as vegetable. Onions, compared with other fresh vegetables, are relatively high in food value, intermediate in protein content and are rich in calcium and riboflavin (Yidau *et al.*, 2020). Recent research has suggested that onions in the diet may play a part in preventing heart disease and other ailments. Onion bulb is rich in phosphorus, calcium and carbohydrates, (Kabrah, 2010; Wiczkowski, 2011). The medicinal value of onions cannot be overemphasized, apart from its culinary purposes, it is also used in making herbs. Little wonder onion is regarded as one of the most consumed and grown vegetable crops in the world (Teshika *et al.*, 2018).

According to a report by Oishimaya (2017), worldwide yearly production of onions stands at over 93 million tonnes with China being the largest producer churning out over 23 million tonnes annually. The report further stated that Nigeria was the 23rd largest producer of onions in the whole world producing above 1,004,153 tonnes annually. Onion has become an important cash crop in Nigeria cultivated in virtually all the irrigable land of all the agro-ecological zones from North-East to the North-West with different local species/varieties (Ibrahim, 2010; Grema & Gashua, 2010). It is produced largely by peasant farmers with little or no idea of adequate post-harvest loss prevention techniques. Their storage techniques involves putting fresh onion bulbs on raised platforms under a shade with no processing. This limitation brings about a colossal loss of the onion under storage. Kanton *et al*. (2008) and Yidau *et al*. (2020) have reported that lack of adequate knowledge of storage techniques and postharvest handling of onions by these farmers has results in onion losses of up to 69% annually. In Nigeria, 20–30% losses of onion produced has been reported

during post-harvest handlings (Torimiro *et al.*, 2020). Further, Tripathi and Lawande (2019) has estimated that in the Sub-Shara Africa, 40 to 50% of the stored onion never reaches to the consumers because of various types of losses. These losses are huge and could drastically reduce annual income of onion farmers and the end users, mostly housewives pay more for a unit at time of scarcity.

Scientific reports have given many reasons for high postharvest losses being experienced in onions value chain, one of which was due to its high moisture content among others (Kang *et al.*, 2007). Therefore, drying has been reported as commonest method of reducing same for extended shelf-life (Kumar *et al.*, 2005; Mota *et al.*, 2010). Unconfirmed scientific reports submitted that onions tend to accumulate microorganisms whenever the bulbs are cut opened to free air. Hence, the needs to investigate the safety of dry onions for human consumption cannot be overemphasized. Further, only scanty data are available in literatures regarding dried onions. This study was an attempt to evaluate the microbiological properties of dried onion slices in order to establish its safety for consumption or otherwise and also to make recommendations regarding the drying of onions in general.

Materials And Method

Sample collection and treatment

Three onion varieties (red, white and cream) were obtained from National Institute for Horticultural Research (NIHORT) Kano sub-station, Nigeria and brought down to NSPRI Ilorin where their initial moisture contents were determined. All samples were subjected to the same processes; they were sorted and cleaned by removing the roots, stems and outer dry layers to achieve consistent composition of onion slices (Liguori *et al.*, 2017; Oniya *et al.,* 2021). Cleaned onions were sliced perpendicular to the axis into pieces 3 mm thick using a stainless steel knife. This slice thickness was chosen based on the specifications for use of commercial dehydrators. The slices with perpendicular cutting could have higher drying rate due to the greater area for moisture removal than the parallel cutting (Vazquez-Armenta *et al.,* 2014; Oniya *et al.*, 2021). Three different drying equipment were used for the research work namely; Solar Cabinet Dryer (SCD), Kerosene Powered Dryer (KPD) and Electrical Powered Dryer (EPD). The daily average temperature recorded for SCD was between 48–50°C while that of KPD and EPD were regulated at three different temperatures (50, 60 and 70°C). The slices were maintained intact in all drying equipment as recommended by Murad & Abdel-Galil (2009). Each sample was placed on a 70% ethanol sterilized aluminum mesh drying tray (12 x 10cm) for drying. The flow chart for the processing of dry onion is as presented in Figure 1.

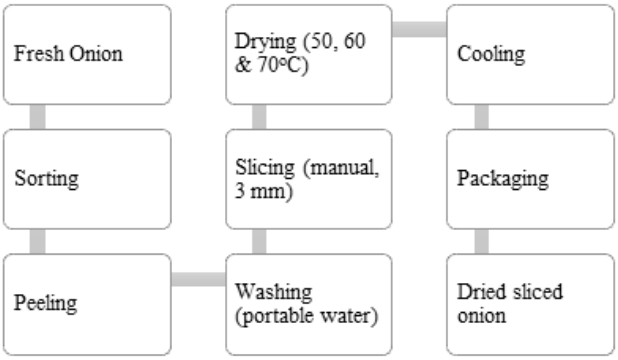

Figure 1: Flow chart for processing dried onion slices

Determination of moisture content (MC)

The moisture content of fresh and dried onion samples was determined following the hot-air oven methods as described by AOAC (2019).The percentage moisture content was calculated by using;

$$Moisture\ content\ (\%) = \frac{W1 - W2}{W1 - Wo} \times 100$$

Where; W_o = weight of empty crucible
W_1 = weight of crucible + sample before drying
W_2 = weight of crucible + sample after drying

Microbial load analysis

Sterilized tweezers were used to place 10g of the dried onion sample into a stomacher bag. The bags were sealed and samples were stored for 5 days before microbial evaluation (Oniya *et al.*, 2021). The fresh sample was stored in the same way. Three different media were used for microbiological examinations to evaluate the impact of drying on different groups of microorganisms. Tryptic Soy Agar (TSA) was used to determine the Aerobic Plate Counts (APC), which were used to enumerate mesophillic bacteria which grow aerobically and are used as general indicator of bacteria growth (Matron, 2001). Potato dextrose agar (PDA) was used to enumerate fungal populations. The last media was Coliform Petrifilms (CP) used to enumerate coliform counts. The media (TSA, CP and PDA) were prepared according to manufacturers' guide.

Serial Dilution

Ninety (90) ml buffer dilution was added to the stomacher bag and mixed to contact the entire onion sample. The bags were placed in a refrigerator (4°C) for 10min to allow rehydration and then stomached for 1 minute before second dilution were made from the contents in sterile 9 cm^3 peptone water dilution. The dilution was vortexed for 10 Sec. and then 1mL were spread plated on TSA and PDA. Additionally, 1 mL of each dilution was added to 3 mL coliform Petrifilms (St. Paul, MN). Triplicates of each dilution were made. The TSA and Coliform Petrifilms were incubated at temperature 35°C for 24 hour while PDA inoculated plate were incubated at temperature 28±2°C for 5 days (Adebola *et al.*, 2018) The plates were enumerated after incubation and the results were recorded as Colony Forming Unit (CFU)/gram of each sample.

Biochemical Tests

Gram staining, Motility, Catalase, Indole, Citrate utilization, and Methyl Red (MR) Test were carried out according to the method Orpin et al. (2017).

Statistical Analysis

Data were analyzed using One-Way Analysis of Variance (ANOVA). New Duncan Multiple Range F-Test (DMRT) was used to determine significant difference among the means of the various samples. These were computed using the Software Statistical Package for Social Sciences (SPSS) version 11.00 (SPSS Inc, Chicago, IL, USA). Significance were determined at the 95% confidence level ($p \leq 0.05$).

Results and Discussion

Effects of drying methods and temperatures on the moisture contents (MC) of onion varieties

The effects of drying methods on the moisture contents (MC) of dried onion slices according to their varieties was shown (Figure 2). The results show that moisture contents of onions (fresh and dried slices) ranged from 5.19–88.29%. All fresh onion varieties (white, cream and red) have high MC (85.55–88.29%). The MC of fresh white onion was significantly lower ($p \leq 0.05$) but no significant difference ($p \geq 0.05$) between the MC of fresh cream and red onions. The high MC recovered from the fresh onions showed that they are prone to high level of deterioration if stored in raw forms. There was no significant difference ($p \geq 0.05$) in the MC of white onion slices dried with different dryers (5.19–7.01%), although their drying rate might differed. The case of cream and red onion varieties were different from that of white onion slices. The MC of cream onion slices dried at 50°C with KPD was significantly high ($p \leq 0.05$) compared to others. This was expected because the average drying temperature of the SCD was 48°C which was lower than any of the other two dryers.

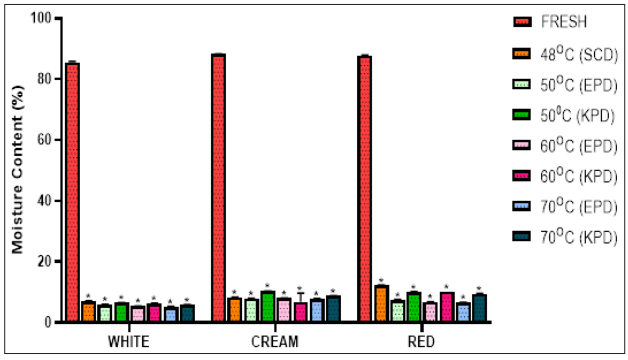

Figure 2: Effects of different drying methods and temperatures on the MC of three varieties of onion slices. SCD=solar cabinet dryer; EPD=electrical powered dryer; KPD=kerosene powered dryer.

In the case of red onion, there was significant difference ($p \leq 0.05$) in the MC of SCD, EPD and KPD onion slices but no significant difference ($p \geq 0.05$) in the MC of onion slices dried at 50, 60 or 70°C (although their drying rate might differ). Similar reports abound in literatures for dried onion slices. Oniya *et al*. (2021) reported that MC of dried white onion slices which were dried with different dryers (solar cabinet, electric powered and kerosene powered dryers) ranged from 5.60–6.83% while that of dried red onion slices ranged from 7.20–14.10%.

Effects of drying methods and temperatures on microbial loads of dried red, white and cream onion slices

The effects of drying methods and temperatures on the microbial loads of dried red, white and cream onion samples were as shown (Tables 1). The Aerobic plate counts (APC), Coliform Counts (CC) and Fungal Counts (FC) of dried red onions ranged from $3.67–5.39\times10^2$ (cfu/g), $1.35–5.39\times10^2$ (cfu/g) and $3.44–4.83\times10^2$ (cfu/g) respectively. In the case white onions, APC, CC and FC of dried white onion slices ranged from $3.11–5.19\times10^2$ cfu/g, $1.31–5.29\times10^2$ cfu/g and $3.43–4.53\times10^2$ cfu/g respectively while that of cream onion samples ranged from $3.30–5.33\times10^2$ cfu/g, $1.33–5.39\times10^2$ cfu/g and $3.42–4.57\times10^2$ cfu/g respectively. Generally, it was observed that APC, CC and FC of red, white and cream onions followed similar trends. Whereas the APC and CC of red, white and cream onion slices were significantly ($p \leq 0.05$) lower than fresh sample, only the samples (red, white and cream) dried with EPD at 60°C and 70°C had significantly lower ($p \leq 0.05$) FC than that of the fresh sample and those dried at other temperatures and with other dryers. However, the study has shown that it is advantageous to dry onion for longer and/or prolonged shelf-life due to reduction in aerobic plate and coliform counts. The aerobic counts recovered from red, white and cream onions were within the stipulated standards of Food Safety and Standards Authority of India regulation of 2011 on dehydrated onion products and American Public Health Association (APHA) values (BAM 2001; FSSAI 2021; Maturin & Peeler, 2021). The final counts were probably composed primarily of aerobic spore formers. According to Matron (2001), aerobic spore formers are the predominant microorganisms in dehydrated species. Spore forming bacteria do normally survive the drying process because they can survive in a high heat environment (Basta & Annamaraju 2022).

Table 1: Effects of drying methods and temperatures on the microbial load of dried slices of three onion varieties (red, white and cream)

Drying Mtd	Tem (°C)	Red onion			White onion			Cream onion		
		APC (x10^2 cfu/g)	CC (x10^2 cfu/g)	FC (x 10^2 cfu/g)	APC (x10^2 cfu/g)	CC (x10^2 cfu/g)	FC (x 10^2 cfu/g)	APC (x10^2 cfu/g)	CC (x10^2 cfu/g)	FC (x 10^2 cfu/g)
Fresh		5.39±0.22^b	5.39±0.17^c	4.70±0.20^b	5.19±0.21^b	5.29±0.27^c	4.50±0.23^b	5.33±0.32^b	5.39±0.17^c	4.40±0.20^b
SCD		3.70±0.00^a	3.27±0.00^b	4.83±0.00^b	3.11±0.00^a	3.05±0.00^b	4.43±0.00^b	3.30±0.00^a	3.01±0.00^b	4.33±0.00^b
EPD	50	3.72±0.70^a	2.72±0.45^{ab}	4.14±0.03^b	3.42±0.70^a	2.52±0.41^{ab}	4.17±0.13^b	3.82±0.70^a	2.70±0.45^{ab}	4.11±0.03^b
	60	3.85±0.19^a	2.29±0.16^{ab}	3.92±0.12^a	3.65±0.29^a	2.25±0.26^{ab}	3.62±0.22^a	3.83±0.19^a	2.24±0.16^{ab}	3.90±0.12^a
	70	3.67±0.42^a	1.35±0.49^a	3.44±0.00^a	3.67±0.40^a	1.31±0.43^a	3.43±0.00^a	3.61±0.42^a	1.33±0.49^a	3.42±0.00^a
KPD	50	3.75±0.47^a	3.18±1.10^b	4.77±0.07^b	3.75±0.37^a	3.14±1.20^b	4.47±0.07^b	3.75±0.47^a	3.18±1.10^b	4.57±0.07^b
	60	3.71±0.49^a	3.05±1.24^b	4.50±0.27^b	3.41±0.44^a	3.02±1.34^b	4.53±0.17^b	3.71±0.49^a	3.05±1.24^b	4.40±0.27^b
	70	3.71±0.45^a	2.00±1.41^{ab}	4.05±0.07^b	3.91±0.45^a	2.05±1.31^{ab}	4.05±0.27^b	3.71±0.45^a	2.00±1.41^{ab}	4.15±0.07^b
Min.		3.67	1.35	3.44	3.11	1.31	3.43	3.30	1.33	3.42
Max.		5.39	5.39	4.83	5.19	5.29	4.53	5.33	5.39	4.57

Results showed mean ± SD of triplicate determinations. Means with different superscript alphabet along the same column are significantly different ($p \leq 0.05$). APC=aerobic plate counts; CC=coliform counts; FC=fungal counts; SCD=solar cabinet dryer; EPD=electrically powered dryer; KPD=kerosene powered dryer.

The high survival of the aerobic spore formers and inactivation of other population of microorganisms would account for the similar final counts. The population that were reduced were most likely vegetative cells, which include coliforms. Coliforms are index organisms which can indicate the increased chances of pathogenic contamination (Kornacki & Johnson, 2001). Coliform measurements are important for onions since they are grown in contact with soil (Oniya *et al.,* 2021).

The study also demonstrated the ability and/or effectiveness of the electrically powered dryer in reducing the fungal contaminations of onions varieties (red, white and cream). In the observation, fungal counts were significantly different for the three drying methods with greater reductions in sample dried with electric dryer. This might probably be due to greater heat fluxes from the electric emitter. The observation was in consonance with literature reports (Kornacki & Johnson, 2001). Further, it was observed that some fungal counts in the dried samples had higher values (although no significant difference) than the fresh samples, this might probably be due to the facts that fresh onions contained antimicrobial action which allows more accurate microbial counts as reported by Rahaman and Perera (1999).

Morphological and biochemical characteristics of bacteria isolates from three onion varieties (red, white and cream)

The morphological and biochemical characteristics of bacteria isolates from three varieties of onions were as shown (Table 2). A total of five (5) predominant and distinct colony were tentatively identified and isolated from three onion varieties. These organisms include both Gram negative and positive ones namely; *Pseudomonas aeruginosa, Bacillus cereus, Enterobacter spp., Staphylococcus aureus* and *Escherichia coli*.

Morphological and microscopic characteristics of fungal isolates from three onion varieties (red, white and cream)

The morphological and microscopic characteristics of fungal isolates from three varieties of onions were as shown (Table 3). A total of five fungi belonging to four general were also isolated and identified to be *Aspergillus flavus, Aspergillus niger, Penicillium sp., Fusarium moniliforme, and Rhizopus stolonifer.*

Percentage Frequency of Bacteria and Fungi Identified from three varieties of fresh and dried onion slices (red, white and cream)

The percentage frequency of bacteria isolates from three varieties of fresh and dried onion slices were as shown (Table 4). The result showed that five bacteria (*Escherichia coli, Pseudomonas sp, Staphylococcus. Aureus and Enterobacter sp*) were isolated from fresh and all dried onion, however most of the isolates are non-spore-forming vegetative cells except for *Bacillus cereus* (Spore former). Some of the identified bacteria such as *S. aureus* are post processing contaminant which are mostly present in the air. The result is in conformity with the report of Savitha (2021), that the most common microorganism in Onion such as *E. coli* that enters the system through water during harvesting. Spores of *Staphylococcus* and Presence of *Pseudomonas sp.*, occur during handling, processing and storage. Kelechi and Joseph (2020) also reported that *E. coli* and B. cereus are most associated with onion deterioration irrespective of either fresh or dried, although the highest contamination in fresh sample is reduced to the safest level in dried samples. The percentage frequency of fungi from fresh and dried onions were as shown (Table 5). It showed that five fungi (*Aspergillus niger, Aspergillus flavus, Rhizopus stolonifer, Fusarium oxysporum and Penicillium digitatum*) were isolated and identified. *R stolonifer* was found to have highest frequency of occurrence across all the onion samples. However *A. flavus* which has been known to be aflatoxin secreting fungi was also present although in lowest percentage.

The report is in line with Savitha (2021) who reported that *Aspergillus sp.* contaminate the onions when carried through the air.

Table 2: Morphological and biochemical identification of bacteria isolates from fresh and dried onion slices (red, white and cream)

Identity of isolate	Cultural characteristics							Morphology									
	Shape	Egde	Colour	Ealevation surface	Colony	Transparency	Cell Shape	Gram	Spore Stain	Capsule	Motility	Coagulase	Catalase	Urease	Citrate	Indole	Oxidase
Pseudomonas aeruginosa	Round	Entire	Pink	Raised	Smooth	Transluscent	Rod	-	-	-	+	-	+	-	+	-	+
Bacillus cereus	Round	Entire	Creamy	Raised	Smooth	Transluscent	Rod	+	+	+	-	-	+	-	+	-	+
Enterobacter sp	Round	Entire	Pink	Raised	Smooth	Transluscent	Rod	-	-	+	+	-	+	-	+	-	-
Staphylococcus aureus	Round	Entire	Yellow	Raised	Smooth	Transluscent	Cocci	+	-	-	-	+	+	-	+	-	-
Escherichia coli	Round	Entire	Pink	Raised	Smooth	Transluscent	Rod	-	-	-	+	-	+	-	-	+	-

Biochemical				
Sucrose	Glucose	Lactose	Maltose	Mannose
_	_	_	_	_
AG	AG	_	AG	A
_	_	AG	_	A
A	A	A	A	AG
AG	AG	AG	A	_

- =Negative, +=Positive, A=Acid, AG= Acid & Gas

Table 3: Morphological and microscopic identification of fungal isolates from three onion varieties

Texture	Morphology	Microscopic characteristics	Fungal Isolates
Floppy	White thick cotton-like colony and orange in the reversed	Sepate hyphae, side shaped macroconidia, conidiophores bears conidia containing conidiospores	*Fusarium moniliforme*
Velvety	Light green/yellowish colony with white to cream edge	Sepate hyphae, unbranched conidiophores scanty sterigmata	*Aspergillus flavus*
Velvety	Whitish to black pigment that latertum, with conidial production, brownish red on the reversed side	Septate hyphae, unbranched conidiophores from the foot of species	*Aspergillus niger*
Powdery	Whitish to Creamy colony that later turns black	Aseptate hyphae, unbranched, sporangiophores arose from foot of rhizoid. Scattered spores which submerged in agar	*Rhizopus stolonifer*
Powdery	Dark green colony with white ring powdery that grows moderately. The reverse side is Cream	Septate hyphae, branched conidiophores with secondary branches metulas. Sterigmata bears round conidia in chain	*Penicillium sp.*

Table 4: Percentage frequency of bacteria isolates from three varieties of fresh and dried onion slices

Drying Methods	Temperature (°C)	Percentage (%) frequency of Identified Bacteria Isolates				
		Escherichia coli	*Pseudomonas sp*	*Staphylococcus. Aureus*	*Enterobacter sp*	*Bacillus cereus*
Fresh	-	55.0	25.0	10.0	5.0	5.0
Solar	50	12.5	12.5	50.0	10.0	15.0
Electric	50	15.0	10.0	50.0	17.5	7.5
	60	13.5	12.5	38.0	30.0	6.0
	70	15.0	22.0	38.0	20.0	5.0
Kerosene	50	15.0	15.0	50.0	10.0	10.0
	60	25.0	18.0	28.0	21.0	8.0
	70	21.0	25.0	27.0	22.0	5.0

Table 5: Percentage frequency of identified fungi from three varieties of fresh and dried onion slices

Drying Methods	Temperature (°C)	Percentage (%) frequency of Identified Fungi				
		Aspergillus niger	*Aspergillus flavus*	*Rhizopus stolonifer*	*Fusarium oxysporum*	*Penicillium digitatum*
Fresh	-	35.0	12.5	43.0	10.0	9.5
Solar	50	28.0	15.0	35.0	12.0	10.0
Electric	50	18.0	13.5	40.0	10.5	18.0
	60	22.0	15.0	38.0	10.0	15.0
	70	20.0	15.0	25.0	20.0	20.0
Kerosene	50	28.0	15.0	35.0	10.0	12.0
	60	18.0	10.0	30.0	22.0	20.0
	70	13.0	10.0	25.0	20.0	32.0

Conclusion

Nigeria is one of the growers and exporting nations of onions yet high rate of deterioration of fresh onion bulbs is being witnessed in the country owing to knowledge gaps for postharvest losses prevention. The lapses in the value chain generated this interest to evaluate the effects of processing on microbiological properties of onion bulbs. The study has shown the possibility of using solar cabinet dryer, electrically powered dryer and kerosene powered dryer in the processing of three varieties of onions into dried slices. It has also shown that the electrically powered dryer is more efficient in the production of safe dried onion as it produced products with reduced microbial load accompanied with reduced moisture content.

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