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ORIGINAL RESEARCH ARTICLE

INTERACTIONS BETWEEN VARIETIES, DRYING METHODS AND PACKAGING MATERIALS ON MOISTURE AND ASH CONTENTS OF DRIED MANGO (*Mangifera Indica*, L) CHIPS

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ABSTRACT

This study examined the interaction of mango varieties (Keith and Julie), drying methods (open sun, solar cabinet, oven) and packaging materials (glass, plastic, corn starch, polyethylene) on moisture and ash content of dried mango chips over four months period, in order to determine the most effective combination for long term storage and quality. Proximate analysis and statistical analysis using ANOVA with LSD were employed. Key findings indicated that the combination of Keith variety, oven drying, and glass packaging yielded the lowest moisture content (5.00%), enhancing storability and reduced microbial spoilage. For ash content, Keith variety, solar cabinet drying, and glass packaging combination retained the highest percentage (2.44%), indicating better quality preservation. Glass packaging emerged as superior to corn starch, plastic and polyethylene due to its non-porous nature and protective qualities. When compared to plastic, it was observed that, because glass had the least effect on the flavor of food while protecting it from external factors; it preserved flavor better but this was not directly tested in this study. However, when properly sealed, com starch could be an option, due to its light weight, low cost, biodegradability, and eco-friendliness. It is recommended that further research be conducted on the effect of glass packaging on flavor of stored food products. Also, on the proper and improved sealing of corn starch packaging.

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1.0 Introduction

Mango *(mangifera indica.* L) fruit is a tree drupe that comes from the Anacardiaceae family and *mangifera* genius. Mango can be included in the category of functional foods, since it provides the human diet with macro and micronutrients and contains a large pool of bioactive compounds that are relevant to improving health and reducing the risk of diseases (Ribeiro, and Schieber, 20 I 0). Mango fruit is rich in a variety of bioactive compounds including polyphenols which are antioxidants and have been shown to exert anti- inflammatory, anti-carcinogenic and anti-aging properties (Elhadi *et al.* 2023). Mango fruit is the second most traded tropical fruit globally and ranks seventh in terms of production (Owino and Ambuko, 2021).

Currently, Malawi is the largest producer in Africa with 2,083,471 MT followed by Egypt with 1,493,538 MT and Nigeria 946,695MT (Ampah *et al.* 2022). In Nigeria, Benue state is the largest producer of mango. The largest variety produced is the German mango variety (Olotu *et al.* 2020). There are different varieties of

mango in Nigeria, most of which are named according to where they are cultivated or produced while others may be due to a nickname generated in the locality in which they are found. They are cotonou mango, german mango/opioro, Benue mango, normal mango (Ogbomosho/Calabar/Abuja mango), Sheri mango, Julie mango, Peter mango (Binta sugar/Jane mango), kerosene mango, Keith mango Olotu *et al.* 2020). Mango, like other fleshy fruits, are highly perishable and seasonal, resulting in significant nutritional losses for consumers and economic losses for farmers (Mangij & Ngoma, 2022). Losses in terms of quality and quantity of *fruits* occur at all stages in the postharvest system from harvesting to consumption (Islam *et al*. 2013). Every year, in developing countries, fruits and vegetables are wasted owing to in-efficient transportation, processing and handling and lack of adequate storage system (Chetna, *et al*. 2021). Due to high postharvest losses of fruits and vegetables, there is the need to process and preserve perishable fruits during bumper harvest and periods of glut to curb waste and to make these fruits available throughout the year in a value-added form. These mango products are derived from appropriate food processing and value- addition technologies that transform fresh mango into shelf-stable products with ideal organoleptic, nutritional and other quality attributes (Owino and Ambuko, 2021). There are several methods of processing mango *fruits.* They include converting the fruits into juice, jam, chips topping, powder etc. (Mahalakshmi., & Murlidhar, 2022).

Drying is an essential operation in the food industry and is the oldest method for extending the shelf-life of food product by inhibiting microbial growth and enzymes. Dried products require less packaging, have better microbiological stability, last longer in storage and weigh less when being transported (Harsh *et al*., 2023). This study was aimed at examining the interaction between the varieties, drying methods and packaging materials on the storability of mango chips in order to determine the most effective combination. Keith and Julie varieties were chosen due to their availability in the study area and also that, while Keith variety in the locality is largely grown by a re-known farmer, Julie variety on the other hand is grown by the majority of farmers. Keith variety is oval in shape, longer and relatively flatter in length compared to Kent variety (Ampah *et al.* 2022). Julie mango also called Saint Julian, is a named mango cultivar that was made popular in the Caribbean. The flavour is very sweet and the texture is very soft and fibreless. Dried foods have a longer shelf-life and expands consumers' options for off-season availability and offers diversity of choice to consumers (Shweta *et al,* 2022).

By knowing the appropriate variety, drying method, packaging material and combination that will enhance the quality and retention of evaluated proximate composition of the material, the study will help farmers and processors of mango chips to curb waste, reduce losses and make mango available all year round in a value-added form that is safe, of high quality and longer shelf life at competitive cost. Manufacturing and processing industries will also profit from low energy consumption and storage space.

2. Materials and Method

The experiment was conducted at the Laboratories of the Departments of Crop Production and Horticulture, Biochemistry, Food Science and Technology and Microbiology, Modibbo Adama University, Yola. Fresh Keith mango fruits at mature-green stage were harvested from Sebore farms in Mayo Belwa Local Government Area of Adamawa State, Nigeria and transported by road to Modibbo Adama University, Yola which is situated between latitude 90°20' 00" and 90°21' 30" N and Longitude 120°29' OO"E and 120°20' OO"E (Adebayo and Zernba, 2020).

Julie variety was also harvested at the same mature-green stage from the Orchard of Modibbo Adama Unjversity, Yola. Both samples were washed with tap water, wiped clean using cotton wool and pre-cooled for 24hrs at room temperature at the laboratory of the Crop Production Department of Modibbo Adama University, Yola. They were subsequently blanched with hot water at 80-100°C for three minutes before peeling with knife for chips production which had approximate thickness of 2.00 - 3.00 mm before the drying process commenced.

The sun-dried samples were kept in a desiccator in the night and brought out during the day for drying. Proximate analysis of both the fresh and dried samples (moisture and ash) were carried out at the Laboratory of Food Science Department of the University, while microbial count was carried out at the Microbiology Laboratory Department before the commencement of storage. The dried samples were then packed in the different packaging materials (glass bottle, cornstarch, plastic and polyethylene) and stored for a period of four months.

The proximate analyses were all carried out in accordance with AOAC Standards (2016). Sun drying method, was carried out on top of a canopy whose surface was covered with black polyethylene sheet (at an average ambient temperature of 3 1 .69°C, RH 54.41%,); Solar cabinet drying method was carried out using a solar

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dryer, locally constructed in Yola, Adamawa State, Nigeria (at an average collector temperature of 32.65°C, RH 56.19%) and oven drying method carried out in an oven (TO, 008GA-34, AKA1-TOKYO, JAPAN) at a constant temperature of 70°C for sixty (60) hours. The packaging materials used were glass bottle, cornstarch, plastic and polyethylene.

The experiment was laid out in split-split plot design in three replications. The main plot factors were the two varieties of Keith and Julie, sub-plot factors were the three drying methods of sun, solar cabinet and oven, while the sub-sub plot factors were the packaging materials of glass bottle, cornstarch, plastic and polyethylene

2.1 Moisture Content

Two grams each of sun dried, solar cabinet dried and oven dried sample were weighed into pre-weighed crucible and dried. The samples were dried for three hours at 105°C after which they were put into a desiccator to allow for cooling; weighed again and the weights recorded. This process was repeatedly carried out until a constant weight was obtained. The difference in weight was calculated as the percentage ratio of wet to dry basis of sample (AOAC, 2016) as given by Equation (I).

$$\mathrm{MC} = \frac{w_b - w_a}{w_b - w_c} X\ 100\% \qquad \text{I}$$

where, MC is Moisture Content, %, w_a is weight of empty dish (g), w_b is weight of empty dish+ sample (g) w_c = weight of empty dish +dried sample (g)

2.2 Ash Content

Two grams each of sun dried, solar cabinet dried and oven dried samples were weighed into a pre-weighed crucible heated for three hours at a temperature of I 00°⁰c before being transferred into a muffle furnace (Model EGF3, Vecstar Furnace at 550°⁰C) till it turned into ash.

The samples were thereafter transferred into a desiccator *to* cool at room temperature and immediately weighed again. This was repeated three times and the average of same was obtained. Percentage Ash content of the sample was calculated as given in AOAC (2016) by Equation (2)

$$\text{Ash Content } \% = \frac{w_2 - w_3}{w_2 - w_1} X\ 100\% \qquad 2$$

where, w_1 is weight of empty crucible (g), w_2 =weight of empty crucible+ sample (g), w_3= weight of empty crucible+ dried sample (g).

3. Results and Discussion

The result of the interaction between varieties, drying methods and packaging materials on the percentage moisture content of dried mango chips in storage in the research done in 2022 is presented in Table I. Highly significant differences (P≤ 0.01) existed in the various interactions between varieties, drying methods and packaging materials on the moisture content of the stored dried mango fruits in the year 2022 storage period of four months (Table I).

The lowest moisture content value in this study, for the interaction between varieties, drying methods and packaging material was recorded by the interaction between Keith variety, Oven drying method and Glass bottle packaging material (5.00%). This could be due to the non-permeability to moisture and air by Glass bottle packaging material. This agreed with the report of Paramount Global, (2023) that glass is incredibly dependable as a material, particularly for food and beverage packaging since it is both impermeable and non-porous. Glass always acted as a strong defense against external influence, preventing any unfavorable changes to the scent, taste or composition of its contained content. The values obtained in this study agreed with the Safe Moisture Content (SMC) value for 'Dried Mango Chip obtained by Afolabi (2014) but also lower than the value for 'Julie mango chip' obtained by the same author.

The highest moisture content value (which is undesirable) in this study, for the interaction between varieties, drying methods and packaging material was recorded by the interaction between Julie variety, Oven drying method and Plastic packaging material (31.49%). This could be due to the permeability to moisture and air by plastic packaging material. In the first storage month, it was observed that there were significant interaction

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(P≤0.01) between the various factors. The interactions between Keith variety, solar cabinet drying methods and cornstarch packaging material and that between Keith variety, solar cabinet drying and plastic packaging material recorded 21.89% and 21.33%, respectively. The lowest value was recorded from the interaction between Keith variety, oven drying method and glass bottle packaging material, which differed significantly lower with percentage moisture content of 4.11%.

Table I: Interaction between Varieties, drying methods and packaging Materials on the Percentage Moisture Content of Dried Mango Chips in Storage in 2022

	Keith			Julie		
Packaging Materials	**Sun Drying**	**Solar cabinet drying**	**Oven Drying**	**Sun Drying**	**Solar cabinet drying**	**Oven Drying**
		First Month				
Glass bottle	16.54	17.45	4.11	16.59	17.45	13.73
Corn starch	22.45	21.89	22.44	19.11	18.08	19.71
Plastic	21.22	21.33	18.33	17.43	18.20	17.87
Polyethylene	18.23	20.22	10.51	15.23	16.09	13.41
P<F	≤0.001					
LSD	1.630					
		Second Month				
Glass bottle	15.22	15.22	4.52	12.16	10.66	10.84
Corn starch	25.44	25.44	25.36	20.17	21.17	21.83
Plastic	25.33	25.33	21.85	15.25	18.00	17.67
Polyethylene	18.97	18.97	17.67	13.17	15.25	16.59
P<F	≤0.001					
LSD	2.511					
		Third Month				
Glass bottle	17.78	19.33	7.22	16.17	20.08	12.04
Corn starch	25.67	28.11	26.67	22.89	27.07	25.05
Plastic	26.89	29.50	25.33	18.08	20.08	18.36
Polyethylene	25.33	25.89	19.33	17.05	17.41	18.41
P<F	≤0.001					
LSD	1.457					
		Fourth Month				
Glass bottle	16.230	31.183	5.000	18.332	17.167	19.220
Corn starch	10.000	9.300	10.335	24.755	28.635	26.582
Plastic	9.067	11.333	11.165	28.333	26.028	31.498
Polyethylene	10.165	9.100	9.447	22.668	21.245	20.738
P<F	≤0.001					
LSD	0.550					

A similar trend was observed in the second month of storage, where a highly significant difference (P≤0.01) was observed between the interactions of Keith variety, oven drying method and glass bottle packaging material that recorded the lowest value of 4.52% in the month and those of Keith variety, sun drying method and corn starch packaging material (25.44%); Keith variety, oven drying method and com starch packaging material (25.36%); and that between Keith variety, sun drying method and plastic packaging material (25.33%), whose values of moisture percentage were respectively the highest recorded in the month. Significant differences were also observed in the other interactions in the same month. The interactions between Keith variety, solar cabinet drying method and cornstarch packaging material and that between Keith variety, solar cabinet drying method and plastic packaging material, with respective values of 24.77% and 24.43%, followed the highest moisture content percentage recorded in the month.

Although significant differences were observed between the various factors in the third month of storage, the highest percentage of moisture content was recorded by the interaction of Keith variety, solar cabinet drying method and plastic packaging material, followed by that of Keith variety, solar cabinet drying and cornstarch packaging material with values of 29.50% and 28.11%, respectively. These interactions were higher (P≤0.01) than those recorded by the interactions of Keith variety, oven drying methods and glass bottle packaging material and that between Julie variety, oven drying method and glass bottle packaging material whose percentage moisture content was 7.22% and 12.04%, respectively, which were the lowest values recorded in the third month of storage period. In the fourth month, the 31.50% and 31.18% moisture content percentages

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were recorded, respectively, by the interactions of Julie variety, Oven drying method and Plastic packaging material and that of Keith variety x solar cabinet drying method and glass bottle packaging materials. These were the highest moisture percentages recorded. These were significantly different from values recorded by the interaction of Keith variety, oven drying method and glass bottle packaging material (5.00%), which had the lowest recorded values, and significantly differed (P≤0.01) from all the other interactions in the month, which also had significant differences between them. The interaction between varieties, dying methods, packaging materials on the percentage moisture content of dried mango chips in storage in 2023 is presented in Table 2.

Table 2: Interaction between Varieties, drying methods and packaging Materials on the Percentage Moisture Content of Dried Mango Chips in Storage in 2023

	Keith			Julie		
Packaging Materials	**Sun Drying**	**Solar cabinet drying**	**Oven Drying**	**Sun Drying**	**Solar cabinet drying**	**Oven Drying**
		First Month				
Glass bottle	11.67	12.73	9.33	16.11	17.32	13.77
Corn starch	14.00	13.67	16.15	18.98	17.89	18.88
Plastic	12.33	14.22	12.67	17.33	18.28	18.17
Polyethylene	11.67	11.95	12.33	15.11	16.19	13.41
P+<F	≤0.001					
LSD	1.594					
		Second Month				
Glass bottle	14.33	11.11	14.22	11.67	10.89	11.56
Corn starch	21.78	21.56	20.33	19.67	21.00	21.11
Plastic	19.33	21.33	16.33	15.22	18.00	18.3
Polyethylene	16.55	15.67	14.33	13.67	15.33	16.33
P<F	≤0.001					
LSD	1.113					
		Third Month				
Glass bottle	18.25	17.22	17.67	15.82	20.00	12.05
Corn starch	25.00	26.03	27.11	22.97	27.22	24.97
Plastic	22.00	21.38	22.87	18.33	20.33	18.26
Polyethylene	20.67	24.16	21.67	17.078	17.56	18.55
P<F	≤0.001					
LSD	0.541					
		Fourth Month				
Glass bottle	19.66	12.59	21.03	18.33	17.33	19.11
Corn starch	24.00	24.11	28.29	24.96	28.73	26.83
Plastic	25.03	25.00	24.55	28.67	26.06	31.67
Polyethylene	21.96	21.00	23.07	22.67	21.54	21.15
P<F	≤0.001					
LSD	0870					

In 2023, there were no significant interactions (P≥0.01) observed in the first month of the storage, though there were highly significant differences (P≤0.01) between the interactions in the second to the fourth month of storage. In the second month of the 2023, the interaction of the Keith variety, oven drying method and cornstarch packaging material recorded moisture content percentage of 20.33% for the stored dried mango chips. Also, in the same month, Julie variety, solar cabinet drying method and glass bottle packaging material recorded 10.89%, which was the lowest value recorded and differed significantly from the highest value of 21.78% recorded by the interaction of Keith variety, sun drying method and cornstarch packaging material.

In the third month of storage, the interaction of Keith variety, solar cabinet drying method and corn starch packaging material recorded 26.03%, following the highest values of 27.22% and 27.11% recorded by the interactions of Julie variety, solar cabinet drying methods and corn starch packaging materials and that between Keith variety, oven drying methods and corn starch packaging material, respectively. These interactions were significantly different (P≤0.01) from the 12.05% recorded by the interaction of Julie variety, the oven drying method and Glass bottle packaging material, which was the lowest value recorded in the month, and significantly different from the rest of the other interactions, which also had significant differences between them. The fourth month of storage indicated that significant differences existed among the various interactions in the month with the interactions of Julie variety, solar cabinet drying method and cornstarch packaging

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material, between Julie variety, sun drying method and plastic packaging material and that between Keith variety, oven drying method and cornstarch packaging material with values of 28.73%, 28.67% and 28.29% respectively following the highest value of 31.67% recorded by the interaction of Julie variety, Oven drying method and Plastic packaging material. Highly significant interactions (P≤0.01) occurred between Keith variety, solar cabinet drying and glass bottle packaging material that recorded the lowest value of 12.59% moisture content percentage of the dried mango chips.

The highest moisture content obtained was from the interaction between Julie variety, Oven drying method and Plastic packaging material (31.67%). This may be because plastic packaging material is permeable to moisture and air. It might also be due to the hygroscopic nature of oven dried products in which higher temperatures are used during the drying process. This agrees with the findings of Yaris and Sezgin (2017) that plastic packaging, which is frequently used in the food industry, has higher permeability to low molecule compounds such as gases, water vapour and organic vapours when compared to either packaging materials.

The interaction between mango varieties, drying methods, and packaging materials shows clear differences in moisture retention based on the permeability of the packaging material. Keith variety, when dried using oven drying method and stored in glass bottles, exhibited the lowest moisture content. This is likely due to the non-permeability of glass to both air and moisture, offering a more controlled environment for dried products. In contrast, Julie variety, dried similarly but packaged in plastic, had the highest moisture content. This higher moisture level can be attributed to the plastic's permeability, which allows for moisture reabsorption and airflow during storage, especially *in* oven-dried products.

Studies back this observation, highlighting that glass containers are excellent barriers to moisture and oxygen, making them more suitable for long-term food storage than plastic alternatives. Plastic packaging materials, such as polypropylene or polyethylene, while widely used for their affordability and versatility, tend to allow for some degree of moisture permeability, which can lead to rehydration in dried products (Miranda *et al.* 2019; Rodriguez-Rojas *et al.* 2019). Furthermore, this aligns with the principles of food packaging where glass, being impermeable, is preferred for products sensitive to humidity, whereas plastic materials, despite their flexibility, might not provide the same level of protection from environmental factors (Ncube *et al.*, 2020).

Lowest Moisture Content in Keith Variety, Oven Drying and Glass Bottle Packaging: The combination of Keith variety, oven drying, and glass bottle packaging resulted in the lowest content. Glass bottles are non-permeable to air and moisture, effectively preventing external moisture from interacting the dried samples. This leads to minimal moisture absorption post-drying, which is vital for maintaining the dried product's quality. Research supports that glass packaging offers superior barrier properties against moisture and oxygen, making it an excellent choice for long-term storage (Hydavi *et al.* 2022). Highest Moisture Content in Julie Variety, Oven Drying and Plastic Packaging: Conversely, Julie variety packaged in plastic after oven drying exhibited the highest moisture content. This could be due to the permeability of plastic packaging, which allows moisture and air to pass through, leading to rehydration of the dried samples. Plastics, like polyethylene or polypropylene are commonly used in food packaging, but they have varying degrees of permeability (Piloni *et al.* 2022). This can lead to higher moisture absorption *during* storage, compromising the dried product's texture and shelf life.

Oven-Dried Samples and Rehydration: Oven drying often causes loss of water in food products, but the high-temperature process can make the samples more prone to rehydration, especially in humid conditions or with packaging materials that allow air to pass through (Ahn *et al.* 2014). This reabsorption of moisture is particularly pronounced with permeable materials like plastic, contributing to the higher moisture content. The interaction between Varieties, drying methods and packaging Materials on the Percentage Ash Content of Dried Mango Chips in Storage in 2022 is presented in Table 3.

The interactions of varieties, drying methods, and packaging material on the ash percentage of dried mango chips in the table indicated that highly significant difference (P≤0.01) in the interaction occurred all through the months of the sampling period. In the first month of samples stored, the interactions of Julie variety, oven drying methods and cornstarch packaging material and that of Julie varieties, oven drying methods and polyethylene packaging material recorded 4.60% and 4.26% of Ash percentages, respectively. These two interactions differed significantly from the rest of the other interactions that occurred in the month.

The interaction of Julie variety, solar cabinet drying method and glass bottle packaging material (4.07%) produced the highest value, while the lowest value of ash (2.00%) in the first month was recorded by Keith variety, sun drying method and polyethylene packaging material. These values differed significantly from those

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of the other interactions. In the second month of the experiment, highly significant interactions (P≤0.01) were observed. The interactions between Julie variety, sun drying method and Glass bottle packaging material gave ash percentage of 5.25%. These were followed by the interaction between Keith variety, solar cabinet drying method and glass bottle packaging material and that between Julie variety, sun drying method and polyethylene packaging material that recorded respective values of 4.83% and 4.08%. The lowest values of 2.08% and 2.25% of ash content percentage were recorded from the interaction of Keith variety, sun drying method and glass bottle packaging material and that between Keith variety, oven drying method and corn starch packaging material, respectively.

Table 3: Interaction between varieties, drying methods and packaging materials on the percentage ash content of dried mango chips in storage 2022

	Keith			Julie		
Packaging Materials	**Sun Drying**	**Solar cabinet drying**	**Oven Drying**	**Sun Drying**	**Solar cabinet drying**	**Oven Drying**
		First Month				
Glass bottle	2.55	3.11	2.67	2.47	4.07	3.72
Corn starch	2.89	2.59	2.57	3.05	3.00	4.60
Plastic	2.33	2.44	2.55	2.53	3.05	3.07
Polyethylene	2.00	2.33	2.67	3.20	2.35	4.26
P<F	≤0.001					
LSD	0.433					
		Second Month				
Glass bottle	2.08	4.83	2.45	5.25	3.92	3.33
Corn starch	3.33	2.95	2.25	3.08	3.50	2.50
Plastic	3.75	3.75	2.92	3.33	3.92	2.92
Polyethylene	3.50	3.48	3.70	4.08	4.83	3.51
P<F	≤0.001					
LSD	0.928					
		Third Month				
Glass bottle	4.00	5.33	4.15	3.25	2.65	3.25
Corn starch	5.12	4.68	4.24	2.59	3.25	3.08
Plastic	3.78	6.00	3.83	2.25	2.67	2.65
Polyethylene	4.39	3.50	3.92	4.92	2.64	3.33
P<F	≤0.001					
LSD	0.682					
		Fourth Month				
Glass bottle	2.99	2.44	2.97	3.00	2.98	2.86
Corn starch	5.00	4.90	4.50	3.32	4.08	2.94
Plastic	3.58	4.72	4.25	2.84	3.25	3.53
Polyethylene	3.00	3.75	3.63	3.00	3.81	2.86
P<F	0.007					
LSD	0870					

In the third month, the interaction of Keith variety, solar cabinet drying method and plastic packaging material recorded 6.00% Ash content percentage. Apart from being the highest value recorded, *it* also differed significantly from the rest of the other interactions in the month. It was followed by 5.33% and 5.12% recorded by the interactions between Keith variety, solar cabinet drying method and glass bottle packaging material and that between Keith variety, sun drying and cornstarch packaging materials, respectively. These were also significantly different (P≤0.01) from the lowest value recorded by the interaction of Julie variety, sun drying method and plastic packaging material (2.25%). In the fourth month, the lowest value recorded by the interaction between Keith variety, solar cabinet drying method and glass bottle packaging material (2.44%) on ash content percentage significantly differed (P≤0.01) from the 5.00% highest value recorded in the month by the interaction of Keith variety, sun drying method and corn starch packaging material. It also differed significantly from the rest of the interactions, which had differences between them too. The interaction between Keith variety, solar cabinet drying method and cornstarch packaging material also recorded a 4.90% Ash content percentage in the same month.

The Interaction between Varieties, drying methods and packaging Materials on the Percentage ash Content of Dried Mango Chips in Storage in 2023 is presented in Table 4.

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Table 4: Interaction between varieties, drying methods and packaging materials on the percentage Ash content of dried mango chips in storage 2023

Packaging Materials	Keith			Julie		
	Sun Drying	Solar cabinet drying	Oven Drying	Sun Drying	Solar cabinet drying	Oven Drying
		First Month				
Glass bottle	2.78	3.00	3.00	3.00	4.11	3.67
Corn starch	3.00	3.27	2.86	2.47	2.95	4.48
Plastic	2.78	2.56	3.11	2.67	5.00	3.11
Polyethylene	3.00	3.33	2.82	3.19	2.33	4.11
P<F	0.025					
LSD	1.594					
		Second Month				
Glass bottle	3.2	3.1	2.8	4.7	3.9	3.2
Corn starch	3.7	3.1	2.9	3.3	3.7	2.7
Plastic	3.0	3.0	2.6	3.3	3.8	3.0
Polyethylene	3.0	2.9	3.3	3.8	5.0	158.7
P<F	0.440					
LSD	89.66					
		Third Month				
Glass bottle	3.09	2.16	2.63	3.22	2.61	3.21
Corn starch	2.53	2.90	2.48	2.47	3.24	3.11
Plastic	2.11	2.22	2.67	2.16	2.61	2.65
Polyethylene	2.10	3.26	2.23	4.50	2.61	3.33
P<F	≤0.001					
LSD	0.350					
		Fourth Month				
Glass bottle	3.56	2.94	2.49	3.00	2.96	3.04
Corn starch	2.11	3.00	2.29	3.31	3.83	3.21
Plastic	3.26	2.78	2.67	3.00	3.18	3.39
Polyethylene	2.22	2.22	1.67	3.00	3.30	3.04
P<F	0.018					
LSD	0.767					

The 2023 period of sampling showed that significant differences (P≤0.01), occurred in the interaction between varieties, drying methods, and packaging materials in all the months of storage with the exception of the second month, where no significant difference (P ≥0.01) was observed. In the first month of samples in store, the interactions of Julie variety, oven drying method and cornstarch packaging material, that of Julie variety, oven drying method and polyethylene packaging material, and that between Julie variety, solar cabinet drying method and glass bottle packaging material (with ash percentage values of 4.48%, 4.11%, and 4.11%, respectively) were the highest values observed in the month. These interactions differed significantly (P≤0.01) from the rest of the other interactions, of which the value of 2.33% recorded from the interaction of Julie variety, solar cabinet drying method and polyethylene packaging material was the lowest value recorded in the month. Also, Julie variety, oven drying method and glass bottle packaging material recorded 3.67% ash percentage in the same month.

There was no significant difference (P≥0.01) in the interaction between varieties drying methods, and packaging materials in the second month of storage, while in the third month, the interactions between Julie variety, sun drying method and polyethylene packaging material had the highest percentage of ash (4.50%). This differed significantly (P≤0.01) from the rest of the other interactions in the month. This was followed by the interaction of Julie variety, oven drying and polyethylene packaging material with 3.33% Ash content percentage, while the values of 2.10%, 2.11%, and 2.16% recorded respectively by the interactions of Keith variety, sun drying method and polyethylene packaging material, Keith variety, sun drying method and plastic packaging material, and that between Keith variety, solar cabinet drying method and glass bottle packaging materials were the lowest values recorded and they differed significantly (P≤0.01) from the highest values recorded in the month. The fourth month of storage showed that Keith variety, oven drying method and polyethylene packaging material (1.67%) had the lowest percentage of ash content in the *whole* of the month, which made it to differ significantly from the rest of the other interactions. Also, in the same month, the 3.83% ash percentage recorded by the interaction of Julie variety, solar cabinet drying method and cornstarch packaging material made it the highest interaction recorded in the month (P≤0.01). The other interactions that occurred were not statistically different from one another.

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Significant difference (P≤0.01) existed in the various interaction between varieties, drying methods and packaging materials with Keith variety, solar cabinet drying method and glass bottle packaging material recording 2.44%. This was below the values obtained by Afolabi (2017) for both 'Dried Mango Chip and Julie Mango Chip while the highest value of ash percentage obtained in this study was from the interaction between Keith variety, sun drying method and corn starch packaging material (5.00%) which was higher than the value obtained by Afolabi (2017) for dried mango chip but lower than the value for dried Julie mango chip. The differences in results could be due to varietal, geographic location, soil, drying method and process. The lowest value of ash percentage obtained in the interaction between Keith variety, solar cabinet drying method and glass bottle packaging material (2.44%) could be because of the non-permeability to moisture and air by glass bottle packaging material that did not allow moisture and air to penetrate through it. This agrees with the report of Glass Packaging Institute, *(2023)* that glass (bottle) is a non-reactive substance that nothing that comes into contact with it will be affected or altered with the correct closure, no air can enter or exit a sealed glass jar.

The highest value of ash percentage obtained from the interaction between Keith variety, sun drying method and com starch packaging material (5.00%) could be due to the porous nature of corn starch packaging material and permeability of plastic packaging material (2.84%) to moisture and air which could have increased the volume of the ash content and also the lower temperature in the sun drying method. This agrees with the findings of Qingji *et al.* (2014) that starch-based films, which have poor tensile properties and high-water vapour permeability on account of their hydrophobic nature and their sensitivity to moisture content.

4. Conclusion

This study examined the interaction of variety (Keith, Julie), drying method (oven, solar cabinet, sun), and packaging material (glass bottle, plastic, polyethylene cornstarch) on moisture and ash contents of dried mango chips. The lowest moisture content-associated with reduced microbial spoilage-was found in the combination of Keith variety, oven drying, and glass bottle packaging. For ash content, Keith variety, solar cabinet drying, and glass bottle packaging best maintained product integrity.

Therefore, when compared to plastic packaging, studies have shown that glass packaging had the least effect on the flavor of the food while protecting it from external influence. Glass packaging may better preserve flavor due to its non-porous nature, but this was not directly tested in the present study. Because glass is non-porous, it has wonderful chemical composition compatibility, due to its pure or undiluted form, making it the best option to package dried food materials; thus, preventing off-flavors. This compatibility allows for increased product storage for longer periods of time. However, when properly sealed, cornstarch packaging material could be an option due to its light weight, low cost, biodegradability and eco-friendliness.

It is recommended that for ash content, Keith-solar cabinet-glass bottle packaging combination should be used as product integrity was best maintained. Since moisture strongly influenced shelf life, the Keith- oven-glass combination is recommended for long-term storage. Glass out-performed plastic, polyethylene and cornstarch due to its non-porous barrier. However, with proper and significantly improved sealing, corn starch packaging is recommended due to its associated advantages of light weight, low cost, biodegradability and eco-friendliness. Further research should be conducted with respect to the effect of glass packaging on the flavor of stored products, and the proper and improved sealing of corn starch packaging in order to maintain the integrity of stored products.

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