Hermetic Bags Effectively Preserve Dried Ziziphus mauritiana Lam. Fruits in Niger

Article *in* Journal of Agricultural Science · April 2022

DOI: 10.5539/jas.v14n5p15

4 authors:

Issoufou Amadou
Dan Dicko Dankoulodo University of Maradi, Niger
85 PUBLICATIONS **2,479** CITATIONS
SEE PROFILE

Baoua Ibrahim
Université Dan Dicko Dankoulodo de Maradi
238 PUBLICATIONS **2,217** CITATIONS
SEE PROFILE

Laouali Amadou
National Institute of Agricultural Research, Niger
54 PUBLICATIONS **980** CITATIONS
SEE PROFILE

Dieudonne Baributsa
Purdue University
112 PUBLICATIONS **2,057** CITATIONS
SEE PROFILE

Journal of Agricultural Science; Vol. 14, No. 5; 2022
ISSN 1916-9752 E-ISSN 1916-9760
Published by Canadian Center of Science and Education

Hermetic Bags Effectively Preserve Dried *Ziziphus mauritiana* Lam. Fruits in Niger

Issoufou Amadou[1], Ibrahim B. Baoua[1], Laouali Amadou[2] & Dieudonné Baributsa[3]

[1] Département des Sciences et Techniques de Productions Végétales, Université Dan Dicko Dankoulodo de Maradi, Maradi BP 465, Niger

[2] Institut National de la Recherche Agronomique du Niger (INRAN), Maradi, Niger

[3] Department of Entomology, Purdue University, West Lafayette, IN, USA

Correspondence: Dieudonne Baributsa, Department of Entomology, Purdue University, West Lafayette, IN 47907, USA. Tel: 1-765-494-8713. E-mail: dbaribut@purdue.edu

Received: February 23, 2022 Accepted: April 2, 2022 Online Published: April 15, 2022

doi:10.5539/jas.v14n5p15 URL: https://doi.org/10.5539/jas.v14n5p15

Abstract

Ziziphus mauritiana Lam. (jujube) is a valuable commercial fruit crop that is delicious and an effective herbal remedy. In the Sahel region of Africa, the jujube fruits are harvested from the wild and eaten dry. Postharvest management poses challenges due to insects, which leads to the degradation of the quality of the fruits. We assessed the performance of the Purdue Improved Crop Storage (PICS) bags for preserving dried jujube fruits from three regions of Niger. After four months of storage, we measured infestation levels, sugar content, and organoleptic parameters. Insect (*Aubeus himalayanus* Voss) population (though low at the beginning) and the number of fruits with holes increased in polypropylene (PP, control) bags by 100 to 212.50% and 7.58 to 12.96%, respectively. The fruit weight loss in PP treatments ranged from 4.64 to 9.94%. In PICS bags, however, pest infestations and damages were comparable to those observed at the initial stage. No significant differences were observed in sugar content of dried jujube fruits kept in PICS and PP bags after four months of storage. No changes were seen in the quality and organoleptic properties of jujube fruits stored in PICS bags; however, they appeared to decrease in PP bags. PICS bags can be effectively used to preserve the quality of dried jujube fruits in the Sahel.

Keywords: airtight storage, fruit postharvest, insect management, PICS bags, Sahel

1. Introduction

Jujube (*Ziziphus mauritiana* Lam.) is a species of the family Rhamnaceae belonging to the order Rhamnales. Native to tropical Asia, this plant provides local populations with a quality food supplement (Bussmann et al., 2020). In the Sahel, all parts of the shrub wood, its fruits, and its roots are used for different purposes. The fruit's pulp is very rich in vitamins, phosphorus, proteins, and mineral salts (Prakash et al., 2021). As a result, jujube constitutes a significant supplement in the diet of rural populations whose food is based mainly on cereals that are low in vitamins and minerals (Ganaba et al., 2007). Fruits are also important nutritional sustenance for families during famines (Ganaba et al., 2007; Prakash et al., 2021). Generally consumed fresh, it is also processed into beverages, compotes, jellies, cakes, and bread in Zimbabwe (Nyanga, 2012).

The jujube fruit is a globose drupe, 1.2-2.5 cm in diameter, with glabrous brownish or purple skin at maturity and contains a large nucleus enclosed in a whitish, flour-like pulp (Abdel-Sattar et al., 2021). Harvesting is based primarily on collecting *Z. mauritiana* fruits in agroforestry parks and natural forests. After harvest from the wild, jujube fruits are traded mainly by women in the Sahel (Tankoano, 2008). The fruits are sold in local markets and are a source of substantial income for the rural populations. Indeed, during the dry season, women and children are heavily involved in the marketing of jujube fruit (Nyanga, 2012). In Niger, the price of jujube fruit varies by region and fluctuates between USD $0.17 to 0.30 per kg (Moussa et al., 2020). The income generated from these sales contributes to the survival of many families (Tembo et al., 2008a).

The commercialization of jujube fruits in sub-Saharan Africa is mostly affected by low production and loss of quality during postharvest (Denis-esdras et al., 2020; Ganaba et al., 2007; Talukdar et al., 2021). Insect pests during fruits storage are one of the major constraints and result in the loss of market value. In the Sahel, there are

limited studies on pests that cause losses in jujube fruits (Tankoano, 2008; Tankoano et al., 2012). Efforts to improve postharvest management of jujube in other regions have focused on how harvesting, drying, treatments (fumigation and controlled atmosphere), storage duration, storage in sealed polythene bags, and temperatures (cold storage) affect the quality of fresh fruits (Lal et al., 2002; Ozturk et al., 2020; Panchal et al., 2021; Stănică et al., 2020; Tembo et al., 2008a, 2008b; Zhang & Li, 2014; Zhao et al., 2019). No research has been conducted to assess the storability of dried jujube fruits using commercially available hermetic bags in the Sahel.

Modified atmosphere has been widely used to address storage pests in dry grain and has the potential to reduce post-harvest losses and maintain the quality of dried products. The Purdue Improved Crop Storage (PICS) bags have been widely used by smallholder farmers to protect more than 15 crops worldwide, including in Niger (Murdock & Baributsa, 2014; Rabé et al., 2021). PICS bags are hermetic airtight containers that control insects by restricting access to air (Murdock et al., 2012). Exploring new applications of the use of the PICS bags for storage of commodities other than grain would bring additional benefits to rural communities. The objective of this study was to assess the performance of commercially available hermetic storage bags in preserving dried jujube fruits (reduce insect pest infestation and maintain nutritional qualities).

2. Method

2.1 Experiment Set Up

This experiment was conducted from 15/04/2018 to 14/08/2018 (4 months) at the laboratory of the Niger National Institute of Agricultural Research (INRAN), Tarna Station in the Maradi region. The average daily temperature varies between 26 and 34 °C and the relative humidity between 20 and 75% (WorldData, 2022). Since dried *Z. mauritiana* fruits are collected from the wild, the only sources of supply are local markets where they are sold by individual collectors. We purchased *Z. mauritiana* fruits from local markets in the cities of Maradi, Mayahi, and Tessaoua in the Maradi region. Two types of bags, Purdue Crop Improved Storage (PICS) and Polypropylene (PP) woven (control) bags, were used to store the *Z. mauritiana* fruits. A scaled-down equivalent of the bags was made by cutting down individual 50 kg bags into smaller sized 35.0 × 40.0 cm bags and sealing them with an electrical heat sealer (Uline H-86 Impulse Foot Sealer; Pleasant Prairie, WI, USA). The bags were filled with 400 g of dried *Z. mauritiana* fruits, and each treatment was repeated three times.

2.2 Data Collection

Infestation: The initial infestation levels was determined by assessing a 100 g sample from each treatment repetition. Each sample was observed to record the number of live insects; number of fruits with holes; insect species, and weight of 100 fruits. The same process was used to assess the infestation level at the end of the experiment.

Moisture Content: Moisture content was measured at the beginning and the end of the experiment using a DHS10A Halogen Drying Analyzer (Shanghai Yoke Instrument Co., Ltd., Shanghai, China). The DHS10A Moisture Analyzer determined the initial weight of the fruit, then quickly heated it with the internal halogen dryer unit, causing water to vaporize. During the desiccation process, the device continuously determined the weight of the fruit and displayed the results in a percentage of dry solid content. A sample from each treatment repetition was used to assess moisture content.

The Sugar Content: Sugar content was obtained using powder of dried *Z. mauritiana* fruits. The compound 3,5-dinitrosalycilic acid (DNS) and D-glucose monohydrate were measured at the National Laboratory (Niamey, Niger). One gram of *Z. mauritiana* powder from each repetition was diluted (vortex) in 100 ml of distilled water and 1 ml of the solution was taken and mixed with 1 ml of distilled water plus 1.5 ml of Dinitrosalicylic Acid (DNS). The mixture was heated for five minutes in boiling water and then cooled to room temperature. Absorbance was taken at 520 nm (Zhao et al., 2008). Sugar content was determined using D-glucose as a standard.

Sensory Evaluation: Sensory evaluation was performed by a panel of 12 graduate students from the Dan Dicko Dankoulodo University of Maradi, Niger. The panel was selected based on previous experience in sensory evaluation and was equally composed of women and men. Each evaluator was offered a small sample of *Z. mauritiana* fruits from each of the three samples expressed above. The samples were subjected to an acceptance test, using a three-point hedonic scale ranging from 0-bad to 3-excellent. Sensory attributes included color, sweetness, flavor, texture of pulp, and general acceptability.

2.3 Data Analysis

Analysis was conducted using SPSS Inc. for IBM software (version 26.0). The ANOVA and SNK tests were used to compare moisture content, insect infestations and damage, and sugar content of dried *Z. mauritiana* fruits.

3. Results

After four months of storage, the moisture content of dried *Z. mauritiana* fruits stored in PICS bags was comparable to that observed at the beginning of the experiment, regardless of the origin of the dried fruits (Table 1). However, in the PP bag treatment, there was an increase in fruit moisture content ranging from 9.01 to 11.57%.

Figure 1. Opened dried *Ziziphus mauritiana* fruits with an insect. Adult *Aubeus himalayanus* Voss was identified as the major pest of stored dried *Ziziphus mauritiana* fruits (Photo by Ibrahim B. Baoua, 2018)

Table 1. Moisture content (%) and sugar content (%) of dried *Ziziphus mauritiana* fruits stored in Purdue Improved Crop Storage (PICS) and polypropylene (PP) bags after four months. Means± standard deviation (SD) in the same column within the same region followed by the same letter are not significantly different (LSD, 5%)

Localities	Treatments	Moisture content (%)	Sugar content (%)
Maradi	Initial	3.94±0.08a	36.38±28.43
	PP bag after 4 months	12.96±0.56b	36.22±32.84
	PICS bag after 4 months	3.88±0.77a	38.96±25.94
	ANOVA	F = 270.07; df = 2/6; P < 0.001	F = 0.19; df = 2/6; P = 0.83
Mayahi	Initial	4.31±0.06a	24.54±21.47
	PP bag after 4 months	15.88±2.76b	36.76±46.01
	PICS bag after 4 months	4.31±0.68a	37.80±24.84
	ANOVA	F = 49.77; df = 2/6; P < 0.001	F = 0.32; df = 2/6; P = 0.74
Tessaoua	Initial	4.24±0.03a*	39.95±37.60
	PP bag after 4 months	13.97±2.63b	49.10±43.45
	PICS bag after 4 months	4.14±0.24a	50.41±9.45
	ANOVA	F = 41.19; df = 2/6; P < 0.001	F = 0.36; df = 2/6; P = 0.70
Overall	Initial	4.16±0.17a	32.29±28.99
	PP bag after 4 months	14.27±2.31b	40.70±37.71
	PICS bag after 4 months	4.11±0.56a	45.39±26.61
	ANOVA	F = 162.15; df = 2/24; P < 0.001	F = 0.80; df = 2/24; P = 0.47

The insect pest species observed on dried *Z. mauritiana* fruits in the three localities was a beetle, *Aubeus himalayanus* Voss (Curculionidae: Coleoptera) (Figure 1). The initial infestation of the fruits was very low and varied from 0.4 to 5 adults per 100 fruits (Table 2). After four months of storage in PICS bags, the level of the pest infestation decreased by 93.4 to 100%, depending upon the origin of the dried fruits. However, there was an

increase in insect infestation of 100 and 212.5% in fruits stored in PP bags purchased in Mayahi and Tessaoua, respectively. There was a decrease in insect infestation of 81.6% for the stock stored in PP bags purchased in Maradi.

There was an increase in the number of holes per 100 fruits of dried *Z. mauritiana* in PP bags after four months, except in Tessaoua; where no changes were observed compared to the initial assessment (Table 2). There was an increase of 12.96% and 7.58% in the number of holes per 100 fruits stored in PP bags for *Z. mauritiana* purchased in Maradi and Mayahi, respectively. The weight of 100 fruits stored in PICS bags did not change after four months of storage. However, in the PP bags, there was a decrease of 4.64% for fruits from Maradi and 9.94% for those purchased in Mayahi. For those from Tessaoua stored in PP bags, the weight of 100 fruits did not change after four months of storage (Table 2).

Sensory evaluation of dried *Z. mauritiana* fruits revealed differences between fruits stored in PICS bags and those kept in PP bags (Figure 2). Fruits stored in PICS bags scored better on all the sensory parameters (color, sweetness, flavor, texture, and general acceptability) when compared to those kept in PP bags. No significant differences were observed in sugar content of dried *Z. mauritiana* fruits stored in PICS and PP bags after four months (Table 2).

4. Discussion

This study demonstrated that insects are major challenges during postharvest storage of dried jujube fruits in Niger. Stone weevil or *A. himalayanus* was identified as the main insect pest of jujube dried fruits from the three regions of Niger. This insect species was identified as a field and storage pest of jujube fruits in India (Karuppaiah, 2015). An inventory of the insects on *Z. mauritiana* fruits in Burkina Faso revealed other species, including a dozen Diptera (flies) and one moth on fruits in bloom (Tankoano et al., 2012).

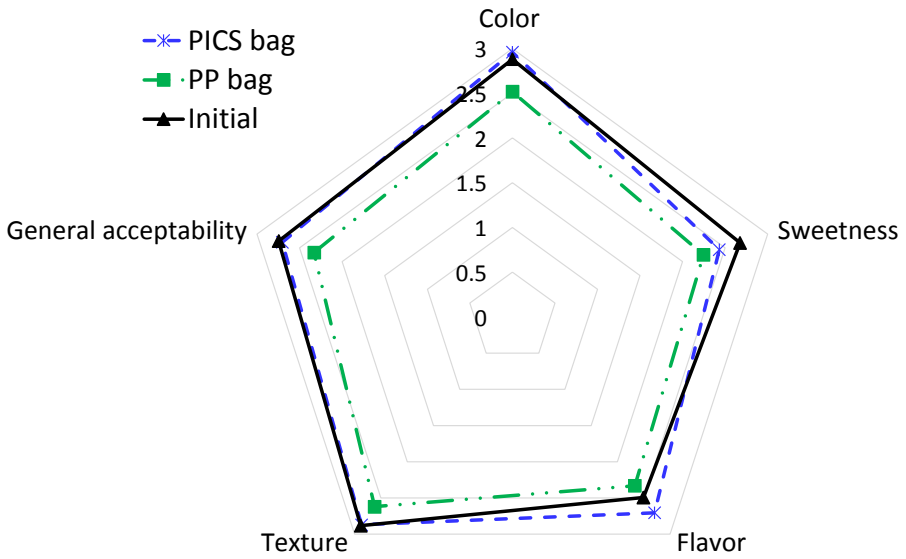

Figure 2. Sensory evaluation of dried *Z. mauritiana* fruits stored in Purdue Improved Crop Storage (PICS) and polypropylene (PP) bags for four months

The infestation levels of jujube fruits varied based on the origin of the dried fruits; with the highest infestation level observed in fruits purchased in Maradi. Studies have shown that the incidence of *A. himalayanus* on jujube fruits is linked to environmental conditions and jujube varieties (Huiqin et al., 2021; Karuppaiah, 2015). The fact that these dried jujube fruits were collected from the wild in three separate regions may explain the differences in the initial infestation levels. Insect infestation continued to increase during storage, particularly, when dried jujube fruits were stored in PP bags; except in fruits purchased from Maradi. The decrease in insect population in fruits purchased from Maradi and stored in PP bags might be explained by the inability of the substrate (dried jujube fruits) to support another generation, due to its initial high insect population. The damage observed (number of holes per 100 fruits) at the beginning of the experiment suggests that insects may have already completed one or few development cycles. Holes made by adults *A. himalayanus* resulted in fruit loss of weight

and quality. After four months of storage, we observed an increase in the number of perforations of 8 to 13% and a decrease in weight of 5 to 10%. Preventing these losses caused by *A. himalayanus* would improve the quality and market value of jujube fruits in Niger (Hama et al., 2019; Kalinganire & Koné, 2011).

Further, moisture content of dried jujube fruits stored in PP bags increased three-fold in four months. Moisture content of dried jujube fruits stored in PP bags increased due to the porosity of the bags and the change in ambient relative humidity during the storage period. As noted, relative humidity during storage increased up to 75% (WorldData, 2022). An increase in relative humidity can result in higher moisture content of stored commodities (Baributsa & Baoua, 2022). The qualitative and organoleptic scores of fruits stored in PP bags were lower than those observed at the beginning of the experiment. Higher moisture content might have affected the sensory scores of dried jujube fruits stored in PP bags after four months of storage. The presence of excessive moisture triggers enzymatic reactions leading to the alteration of the quality of the fruits of *Z. mauritiana* (Badii et al., 2014). No changes were observed in the total sugar content of dried jujube fruits stored in PP bags. Similar results were obtained in a previous study where minimal changes in sugar content of jujube fruits were observed during drying or storage (Pu et al., 2018). The lack of differences in sugar content between treatments might be due to the high variability in the data.

Table 2. Insect infestation, damage (holes), and weight loss of dried *Ziziphus mauritiana* fruits from three regions of Niger stored in Purdue Improved Crop Storage (PICS) and polypropylene (PP) bags after four months. Means±standard deviation (SD) in the same column within the same region followed by the same letter are not significantly different (LSD, 5%)

Localities	Treatments	Measurements per 100 fruits		
		Live adults of *A. himalayanus*	Holes by *A. himalayanus*	Weight (g)
Maradi	Initial infestation	5.00±0.52a	66.50±3.84a	80.98±0.82a
	PP bag after 4 months	0.92±0.36b	83.10±3.55b	77.22±0.87b
	PICS bag after 4 months	0.33±0.14b	60.25±7.80a	80.52±1.21a
	ANOVA	F = 30.75; df = 2/6; P < 0.001	F = 2.40; df = 2/6; P = 0.02	F = 4.00; df = 2/6; P = 0.03
Mayahi	Initial infestation	0.46±0.19a	66.62±3.24a	76.37±1.08a
	PP bag after 4 months	0.92±0.26a	79.58±2.63b	68.78±1.21b
	PICS bag after 4 months	0.00±0.00b	63.17±5.55a	76.62±1.80a
	ANOVA	F = 3.93; df = 2/6; P = 0.03	F = 3.95; df = 2/6; P = 0.03	F = 9.49; df = 2/6; P < 0.001
Tessaoua	Initial infestation	0.4±0.04a	41.00±2.91a	79.54±0.81a
	PP bag after 4 months	1.25±0.30b	48.58±1.86a	77.27±1.49a
	PICS bag after 4 months	0.00±0.00a	41.58±2.65a	79.44±1.69a
	ANOVA	F = 22.97; df = 2/6; P < 0.001	F = 1.83; df = 2/6; P = 0.172	F = 0.99; df = 2/6; P = 0.38
Overall	Initial infestation	1.95±2.64a	58.04±14.76a	78.96±2.36a
	PP bag after 4 months	1.03±0.19a	70.42±19.00a	74.42±4.89a
	PICS bag after 4 months	0.11±0.19a	55.00±11.71a	78.86±2.01a
	ANOVA	F = 0.76; df = 2/24; P < 0.001	F = 0.89; df = 2/24; P = 0.449	F = 2.02; df = 2/24; P = 0.16

The PICS technology was effective in suppressing the increase in the population of *A. himalayanus*, stopped further damage, and minimized losses on dried jujube fruits. In addition, PICS bags were able to maintain good organoleptic properties of the dried jujube fruits. The sensory scores of dried *Z. mauritiana* fruits stored in PICS bags were numerically higher than those stored in PP bags. The suppression of insect population and the minimal change in moisture of the dried jujube fruits stored in PICS bags likely contributed to the preservation of the quality of the stored product. Hermetic storage technologies have been shown to suppress insect populations and maintain constant relative humidity inside airtight containers regardless of the prevailing ambient environmental conditions (Baoua et al., 2018). The absence of oxygen caused the desiccation and death of insects (Murdock et al., 2012). Further, hermetic storage has proven to be effective in preserving fresh jujube fruits during short-term storage. Packed fresh jujube in sealed polyethylene bags for four days showed better qualitative and organoleptic scores than fruits stored in non-airtight bags (Lal et al., 2002). In addition, fresh jujube fruits stored under modified atmosphere for 49 days presented the same appearance compared to those observed at the beginning of the experiment (Reche et al., 2019). PICS bags can preserve dried jujube fruits and help rural women fetch better prices and increase their income (Agúndez et al., 2020; Kalinganire & Koné, 2011).

5. Conclusion

This study demonstrates that hermetic PICS bags are effective at preserving dried *Z. mauritiana* fruits during a four-month storage period. *A. himalayanus* was identified as the main insect pest of dried *Z. mauritiana* fruits during storage. The PICS technology was able to suppress insect multiplication and damage of dried jujube fruits. Storage in PICS bags maintained the quality and sensory attributes of the dried jujube fruits. Thus, there should be efforts to increase awareness among smallholder farmers in the Sahel on the use of PICS bags to preserve the quality of dried *Z. mauritiana* fruits during storage.

Acknowledgements

We thank the Bill and Melinda Gates Foundation (BMGF) for funding this study through the PICS3 project (grant # INV-006972) to Purdue University.

References

Abdel-Sattar, M., Almutairi, K. F., Al-Saif, A. M., & Ahmed, K. A., (2021). Fruit properties during the harvest period of eleven Indian jujube (*Ziziphus mauritiana* Lamk.) cultivars. *Saudi J. Biol. Sci., 28*, 3424-3432. https://doi.org/10.1016/j.sjbs.2021.03.006

Agúndez, D., Lawali, S., Mahamane, A., Alía, R., & Soliño, M. (2020). Farmers' preferences for conservation and breeding programs of forestry food resources in Niger. *Forests, 11*, 697. https://doi.org/10.3390/f11060697

Badii, F., Farahnaky, A., & Behmadi, H. (2014). Effect of storage relative humidity on physical stability of dried fig. *J. Food Process. Preserv., 38,* 477-483. https://doi.org/10.1111/j.1745-4549.2012.00797.x

Baoua, I. B., Bakoye, O., Amadou, L., Murdock, L. L., & Baributsa, D. (2018). Performance of PICS bags under extreme conditions in the Sahel zone of Niger. *J. Stored Prod. Res., 76*, 96-101. https://doi.org/10.1016/j.jspr.2018.01.007

Baributsa, D., & Baoua, I. B. (2022). Hermetic bags maintain soybean seed quality under high relative humidity environments. *J. Stored Prod. Res., 96*, 101952. https://doi.org/10.1016/j.jspr.2022.101952

Bussmann, R. W., Paniagua-Zambrana, N. Y., Njoroge, G. N., Turi, M. A., & Jan, H. A. (2020). *Ziziphus jujuba* Mill. *Ziziphus mauritiana* Lam. *Ziziphus mucronata* Willd. Rhamnaceae. *Ethnobotany of the Mountain Regions of Africa* (pp. 1-9). Springer, Cham. https://doi.org/10.1007/978-3-319-77086-4_174-1

Denis-esdras, A. A., Sylvain, O. N., E, S. H., Agnero, M., & Seguena, S. (2020). Wild plants with edible fruits commercialized in markets in the city of Daloa, Central-West of the Côte d'Ivoire : Specific diversity, origin and economic fallout. *GSC Advanced Research and Reviews, 4*, 23-30. https://doi.org/10.30574/gscarr.2020.4.3.0071

Ganaba, S., Kiéni, B., Barry, H., & Coulibaly, B. (2007). Introduction de cultivars de jujubier (*Ziziphus mauritiana* Lam.) en zone sahélienne du Burkina Faso. *Fruits, 62*, 247-254. https://doi.org/10.1051/fruits:2007020

Hama, O., Tinni, I., & Baragé, M. (2019). Diversité et importance des produits forestiers non ligneux d'origine végétale dans la commune rurale de Tamou, au sud-ouest du Niger, Afrique de l'Ouest. *Rev. Ivoirienne des Sci. Technol., 34*, 191-15. https://doi.org/10.21474/IJAR01/9824

Huiqin, L., Qianliang, L., Jinliang, W., & Dan, W. (2021). Main diseases and pests of Jujube and control strategies in Shanx. *J. Landsc. Res., 13*, 99-101. https://doi.org/10.16785/j.issn1943-989x.2021.2.021

Kalinganire, A., & Koné, B. (2011). *Ziziphus mauritiana, Jujubier.* Conservation and Sustainable Use of Genetic Resources of Priority Food Tree Species in sub-Saharan Africa. Bioversity International, Rome, Italy .

Karuppaiah, V. (2015). Seasonality and management of stone weevil, *Aubeus himalayanus* Voss (Curculionidae: Coleoptera): An emerging pest of Indian Jujube (*Ziziphus mauritiana* L.). *African J. Agric. Res., 10*, 871-876. https://doi.org/10.5897/AJAR2013.8154

Lal, G., Fageria, M. S., Gupta, N. K., Dhaka, R. S., & Khandelwal, S. K. (2002). Shelf-life and quality of ber (*Ziziphus mauritiana* Lamk) fruits after postharvest water dipping treatments and storage. *J. Hortic. Sci. Biotechnol., 77*. https://doi.org/10.1080/14620316.2002.11511541

Moussa, M., Abasse, T., Rabiou, H., Aboubacar, M., & Mahamane, L. (2020). Analysis of the fruit value chain of two priority food woody species of Central Southern Niger, West Africa. *Open J. For., 10*, 277-292. https://doi.org/10.4236/ojf.2020.103018

Murdock, L. L., & Baributsa, D. (2014). Hermetic storage for those who need it most -subsistence farmers. In F. Arthur, R. Kengkanpanich, W. Chayaprasert, & D. Suthisut (Eds.), *11th International Working Conference on Stored Product Protection* (pp. 310-323). Chang Mai, Thailand. https://doi.org/10.14455/DOA.res.2014.56

Murdock, L. L., Margam, V., Baoua, I., Balfe, S., & Shade, R. E. (2012). Death by desiccation: Effects of hermetic storage on cowpea bruchids. *J. Stored Prod. Res., 49*, 166-170. https://doi.org/10.1016/j.jspr.2012.01.002

Nyanga, L. K. (2012). *Ziziphus mauritiana (masau) fruits fermentation in Zimbabwe: From black-box to starter culture development*. Wageningen University, Wageningen, The Netherlands.

Ozturk, B., Aglar, E., Gun, S., & Karakaya, O. (2020). Change of fruit quality properties of Jujube fruit (*Ziziphus Jujuba*) without stalk and with stalk during cold storage. *Int. J. Fruit Sci., 20*. https://doi.org/10.1080/15538362.2020.1834901

Panchal, B. H., Patel, N. A., & Rathod, M. B. (2021). Effect of post harvest treatments on storage quality of Ber (*Ziziphus mauritiana* Lamk.) under cold storage condition cv. Gola. *Int. J. Curr. Microbiol. Appl. Sci., 10*. https://doi.org/10.20546/ijcmas.2021.1006.017

Prakash, O., Usmani, S., Singh, R., Singh, N., Gupta, A., & Ved, A. (2021). A panoramic view on phytochemical, nutritional, and therapeutic attributes of *Ziziphus mauritiana* Lam.: A comprehensive review. *Phyther. Res., 35*, 63-77. https://doi.org/10.1002/PTR.6769

Pu, Y., Ding, T., Wang, W., Xiang, Y., Ye, X., Li, M., & Liu, D. (2018). Effect of harvest, drying and storage on the bitterness, moisture, sugars, free amino acids and phenolic compounds of jujube fruit (*Zizyphus jujuba* cv. Junzao). *J. Sci. Food Agric., 98*. https://doi.org/10.1002/jsfa.8507

Rabé, M. M., Baoua, I. B., Baributsa, D. (2021). Adoption and profitability of the Purdue Improved Crop Storage technology for grain storage in the South-Central Regions of Niger. *Agronomy, 11*, 2470. https://doi.org/10.3390/agronomy11122470

Reche, J., García-Pastor, M. E., Valero, D., Hernández, F., Almansa, M. S., Legua, P., & Amorós, A. (2019). Effect of modified atmosphere packaging on the physiological and functional characteristics of Spanish jujube (*Ziziphus jujuba* Mill.) cv "Phoenix" during cold storage. *Sci. Hortic., 258*. https://doi.org/10.1016/j.scienta.2019.108743

Stănică, F., Dicianu, D. E., Butcaru, A. C., & Liu, M. J. (2020). Jujube fruits behavior at controlled atmosphere storage. *Acta Hortic., 1287*. https://doi.org/10.17660/ActaHortic.2020.1287.40

Talukdar, N. R., Choudhury, P., Barbhuiya, R. A., & Singh, B. (2021). Importance of non-timber forest products (NTFPs) in rural livelihood: A study in Patharia Hills Reserve Forest, northeast India. *Trees, For. People, 3*, 100042. https://doi.org/10.1016/j.tfp.2020.100042

Tankoano, M. P. (2008). *Étude de l'entomofaune et des productions fruitières chez trois variétés indiennes de Ziziphus mauritiana Lam. (Rhamnaceae) introduites au Burkina Faso*. Ouagadougou, Burkina Faso.

Tankoano, P. M., Diallo, O. B., Ouedraogo, S. N., Some, N. A., Noula, K., & Kalinganire, A. (2012). Inventaire des insectes nuisibles aux fruits des variétés indiennes de *Ziziphus mauritiana* Lam. (Rhamnaceae) au Burkina Faso. *Fruits, 67*, 189-200. https://doi.org/10.1051/fruits/2012012

Tembo, L., Chiteka, Z. A., Kadzere, I., Akinnifesi, F. K., & Tagwira, F. (2008a). Blanching and drying period affect moisture loss and vitamin C content in *Ziziphus mauritiana* (Lamk.). *African J. Biotechnol., 7*. https://doi.org/10.4314/ajb.v7i17.59235

Tembo, L., Chiteka, Z. A., Kadzere, I., Akinnifesi, F. K., & Tagwira, F. (2008b). Storage temperature affects fruit quality attributes of Ber (*Ziziphus mauritiana* Lamk.) in Zimbabwe. *African J. Biotechnol., 7*. https://doi.org/10.4314/ajb.v7i17.59234

WorldData. (2022). *Climate in Maradi (Niger)*. Retrieved March 29, 2022, from https://www.worlddata.info/africa/niger/climate-maradi.php

Zhang, S., & Li, N. (2014). Effects of carbon monoxide on quality, nutrients and antioxidant activity of post-harvest jujube. *J. Sci. Food Agric., 94*, 1013-1019. https://doi.org/10.1002/jsfa.6364

Zhao, K., Xue, P. J., & Gu, G. Y. (2008). Study on determination of reducing sugar content using 3,5-dinitrosalicylic acid method. *Food Sci., 9*, 534-536.

Zhao, Y., Zhu, X., Hou, Y., Wang, X., & Li, X. (2019). Effects of nitric oxide fumigation treatment on retarding cell wall degradation and delaying softening of winter jujube (*Ziziphus jujuba* Mill. cv. Dongzao) fruit during storage. *Postharvest Biol. Technol., 156*. https://doi.org/10.1016/j.postharvbio.2019.110954

Copyrights