Sri Lankan Journal of Technology
Research

SLJoT
2021 2(01) 1-7
ISSN 2773-6970

Effect of Modified Atmosphere Storage on Quality Characteristics of Dehydrated Jack Fruits

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Received: 09-11-2020 * Accepted: 02-05-2021 * Published Online: 30-06-2021

***Abstract*—**The quality deterioration of agricultural produces with the time is a major problem in storage. Modified atmosphere packaging is used as an alternative technique for the chemical preservation of food products. This study investigated the efficiency of modified atmosphere treatments with carbon dioxide (CO_2) or nitrogen (N_2) gas for the quality preservation of dehydrated jack fruit. The color, moisture content, pH, Brix value, titratable acidity, and microbial quality of the modified atmosphere treated dehydrated jack fruits were investigated. The color of the dehydrated jack fruit did not show any significant difference (p>0.05) before and 60 days after treated with 99% CO_2 gas. The yellowness (b* value) of the dehydrated jack fruit samples shown a significant difference (p<0.05) to the 99% N_2 treatment but lightness (L* value) and redness (a* values) did not have any significant difference (p>0.05) to the treatment. The modified atmosphere storage did not have any significance (p>0.05) on moisture content, pH, and titratable acidity values of jackfruit but Brix value and microbial population have shown significant difference (p>0.05) during the 60 days of storage at 27 ± 2 °C and 75 ± 5% RH. In conclusion, modified atmosphere gases preserved quality characteristics of dried jackfruit than hermetic storage condition. Since, both inert gases have same effect on the quality characteristics of jackfruits without considerable significant.

***Keywords*—**Modified atmosphere, Dehydrated Fruits, Jackfruit, Quality, Carbon dioxide, Nitrogen

I. Introduction

Major quality parameters associated with dried food products are the color, appearance, shape of product, flavor, microbial load, porosity, bulk density, texture, rehydration properties, water activity and chemical stability, preservatives, and freedom from pests, insects and other contaminants, as well as freedom from taints and off-odors (Perera, 2005). The controlled atmosphere (CA) and modified atmosphere (MA) treatments will not affect the quality of dried fruit than normal atmospheric storage. Modified atmosphere packaging (MAP) has beneficial effects in terms of water loss prevention, delaying of browning, color retention and lowering microbial populations (Siddiq *et al*., 2020).

The major effects found in the dry fruits stored under atmosphere conditions are respect to changing of water activity, color and the formation of sugar crystals on the surface (Sen *et al*., 2010; Prasantha and Amunogoda, 2013). According to the MA study, changes that occurred in fruit total soluble solids and titratable acidity and firmness after the treatment and normal storage condition are not significantly different (Siddiq *et al*., 2020). Fruit color may change during drying and storage due to several chemical and biochemical reactions. Oxidization of fruit phenolic compounds and further polymerizes into form brown pigments during storage (Sen *et al*., 2010). Dried fruits slowly lose their quality during storage depending on storage time and the prevailing storage environmental conditions (Fennema and Tannenbaum, 1976). Therefore, dry fruits and vegetables stored under low O_2 content but high in CO_2, N_2 or low pressure (Prasantha, 2020) may help to reduce the enzymatic and non-enzymatic oxidation process.

Most of the dry food commodities such as grains, spices, nuts, dehydrated fruits and vegetables are organically grown and exported in bulk to Europe and Mediterranean countries as organic products. In some instances, export restrictions are imposed to Sri Lankan commodities due to records of pest infestation, fungal infections and pesticide residues in the product (Prasantha, 2020). Therefore, the food industry is encouraged to search for an alternative non-chemical pest control technique for the protection of stored food (Fields and White, 2002). CA/MA storages are cost effective as an alternative to chemical fumigation and are leave no chemical residues on the fruit (Prasantha, 2020). Different type of MA storage conditions is effective in controlling different species of pest and may prevent from further quality deteriorations. Therefore, it is important to identify the effective MA treatment, which is compatible for specific condition, to reduce the adverse effects of pest attack and quality deterioration of product during the storage period. On other hand, the treatment method should be economical and acceptable for the food industry.

Increasing the CO_2 level in the headspace will prolong their shelf life with little or no adverse effect on quality (Kaliyan *et al*., 2007). Supercritical CO_2 has been successfully used for inactivating a wide range of microorganisms such as yeasts and bacteria (Dillow *et al*., 1999). Nitrogen inhibits the growth of aerobic organisms and, consequently, increases the shelf life of food products (Conte *et al*., 2013). Most studies on CO_2 atmospheres and bacterial growth make the observation that the pH of the growth medium is decreased (Moradinezhad *et al*., 2018). CO_2 can dissolve in materials and reduce their pH (Sanjeev and Ramesh, 2006). The objective of this study is to evaluate the effect of different inert gasses on the quality characteristics of dehydrated jackfruits under modified atmospheric conditions.

II. Material and Methods

The study carried out in Department of Food Science and Technology, Faculty of Agriculture, University of Peradeniya. Dried jack fruits samples were collected from HJS condiments (Pvt.) ltd., Biyagama, Sri Lanka. To study the effect of MA treatment with N_2 or CO_2 on fruit quality, 200 g dried jackfruit packed in Nylon/ Linear low-density polyethylene (LLDPE) (15cm ×10cm) laminated bags. The bags were perforated to facilitate the gas exchange with the outside environment. Package samples were kept inside the treatment desiccators (2 l) separately and maintained the MA condition for 2 months at 27 ± 2 °C and 75 ± 5% R.H. Quality characteristics of dried jack fruit samples were assessed before and after MA treatment either using 99% CO_2 or 99% N_2 gas. Triplicated treatments for moisture content, pH, Brix value, color, titratable acidity and microbiological study were conducted for the MA treated samples. Sealed control group packages were kept in an ambient condition (27 ± 2 °C and 75 ± 5% R.H) for 2 months without any MA treatments. Quality of the control groups were also evaluated accordingly without inert gas treatment after 2 months of storage.

Dry fruit sample of 100 g was dried in 105 °C for 3 hours using a forced air-drying oven (Model:Thermo tech, 150 l) until constant weight achieved (AOAC,1999). The surface color of dried jack fruits was measured using a colorimeter (CHN Spec, CS 10, China) by measuring the both sides of the dried jack fruit samples. The colorimeter was calibrated with a white surface. Measurements were recorded as L (lightness), +a (redness), +b (yellowness) CIE color co-ordinates (Sen *et al*., 2010).

Dry jackfruit samples were (100 g) hydrated by dipping 100 ml distilled water in 120 min and minced using a blender. The minced slurry was centrifuged at 4000 rpm for 15 min and filtered through a Whatman No. 41 filter paper using a vacuum filter. The Brix value of the filtrate sample was measured using a handheld refractometer (Kyowa, HR-1, Japan).

Titratable acidity of the filtrate sample was determined (as citric acid) by diluting 5 ml of solution in 25 ml of distilled water. The diluted solution was titrated against 0.1 N sodium hydroxide solution with phenolphthalein as an indicator (AOAC, 2000). Acidity determined using the following equation (1).

$$Titratable\ acidity\% = [(N \times V1 \times E)/(V2 \times 1000)] \times 100 \quad (1)$$

Whereas,

- N = Normality of titrant
- V1 = Volume of titrant
- E = Equivalent weight of predominant acid
- V2 = Volume of the sample

The pH of the filtrate sample was measured using digital bench top pH meter (Starter 3100, OHAUS, USA) at 27 °C (AOAC, 2002).

Total plate count (TPC) and yeast and mold tests were done before and after the MA treatment. Dried jackfruit (10 g) was aseptically placed into a stomacher bag containing 90 ml of NaCl (0.85% W/V) and homogenized using a bag mixer for 4 minutes. Samples (1ml) diluted for decimal series using 9 ml NaCl (0.85% W/V) up to four decimals, respectively for TPC and yeast and mold test. For TPC test, 20 ml of plate count agar (PCA media) was poured into sample spread Petri dish and mixed well. TPC cultures were incubated at 30 °C for 24 hours period (AOAC, 2002). For yeast and mold test, 20 ml of Dichloran rose Bengal Chloramphenicol agar (DRBCA) media was poured into sample spread petri dish and mixed well. Yeast and mold cultures were incubated at 28 °C for 48 hours period (AOAC, 2012). All procedures were done aseptically under fume hood.

All treatments and controls were replicated 2-3 times appropriately. Quality characteristic values were analyzed using one-way analysis of variance (ANOVA) and the simple two sample t-test was used to separate the means at 95% confidence interval (SAS Institute 1990).

III. Results

A. Colour

The L* and a* values of the dehydrated jack fruit samples before and after 60 days of storage in 99% N_2 gas treatment did not show any significant difference ($p>0.05$) but b* value shown significant difference ($p<0.05$) to the N_2 treatment. Fu *et al*. (2017) observed a same result in dehydrated lemon slices stored in MAP. But L*, a* and b* values of the dehydrated jack fruit samples before and after treated with 99% CO_2 gas did not show any significant difference ($p>0.05$) indicating that CO_2 has no effect on the color of dehydrated jackfruits (Table 1). Akev *et al*. (2018) also found a similar result for the color values of raisins stored under controlled atmosphere storage condition established using CO_2 gas.

B. Moisture Content

Moisture content (MC) of the dehydrated jack fruit samples before and 60 days after 99% CO_2 gas treatment did not show any significant difference ($p>0.05$) but 99% N_2 gas treated samples showed significant difference ($p<0.05$). Moisture content of the control samples maintained in hermetic condition under atmosphere also did not show any significant difference ($p>0.05$) compare to the treatments (Figure 1). According to the Martínez-Ferrer *et al*. (2002), there was no significant reduction observed for MC stored under MAP condition using the mixture of CO_2 and N_2 gasses.

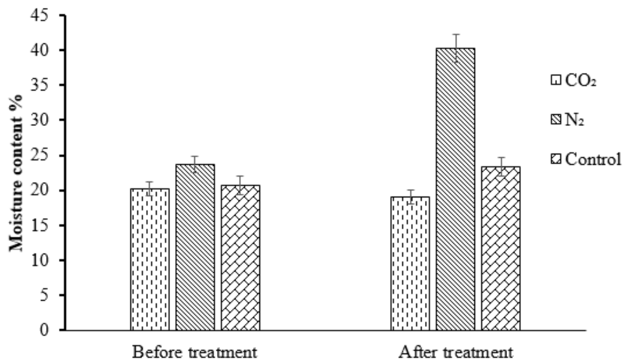

Figure 1: Changes of moisture content value of initial and 60 days stored dehydrated jack fruit samples after MA treatments maintained at 27 ± 2 °C temperature and 75 ± 5% RH. Lines on the vertical bars represent standard error of the mean.

C. pH

The pH values of the dehydrated jack fruit sample compare to the control sample, before and 60 days after 99% N_2 and 99% CO_2 gas treatments did not show any significant difference ($p>0.05$) during the study (Figure 2). Rodrigues *et al*. (2006) also reported that there was no significant difference observed during modified atmospheric storage of osmo-dehydrated papaya fruits.

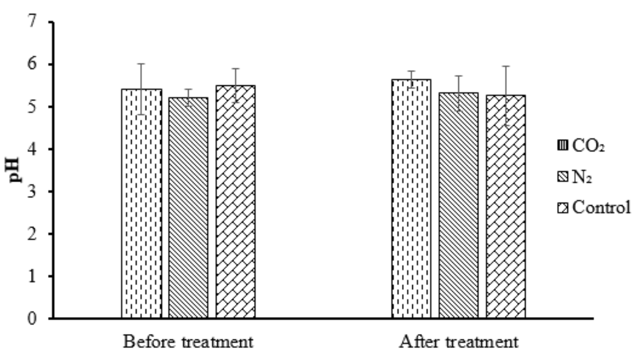

Figure 2: Change of pH value of initial and 60 days stored dehydrated jack fruit samples after MA treatments maintained at 27 ± 2 °C temperature and 75 ± 5% RH. Lines on the vertical bars represent standard error of the mean.

D. Brix Value

Brix value of the dehydrated jack fruit sample before and 60 days after 99% N_2 and 99% CO_2 gas treatments showed significant difference ($p<0.05$) during the study. However, brix value of the control samples did not show any significant difference ($p>0.05$) during the study period (Figure 3). Martinéz-Romero *et al*. (2003) found a similar result for the brix value of grapes stored under modified atmosphere.

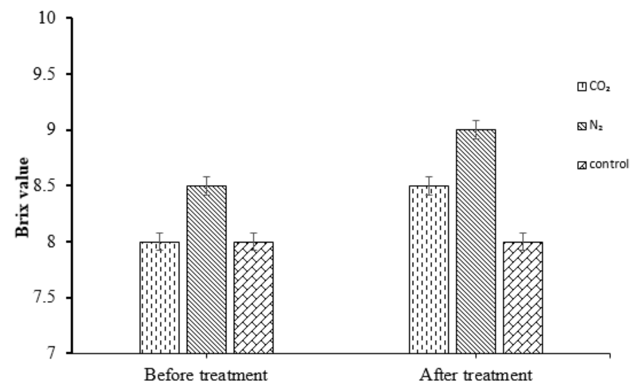

Figure 3: Change of brix value of initial and 60 days stored dehydrated jack fruit samples after MA treatments maintained at 27± 2 °C temperature and 75 ± 5% RH. Lines on the vertical bars represent standard error of the mean.

E. Titratable acidity

Titratable acidity of the dehydrated jack fruit sample before and 60 days after 99% N_2 and 99% CO_2 gas treatments compare to the control sample did not show any significant difference ($p>0.05$) during the study (Figure 4). But, Martinéz-Romero *et al*. (2003) found a slight reduction in the titratable acidity of grapes stored under modified atmosphere.

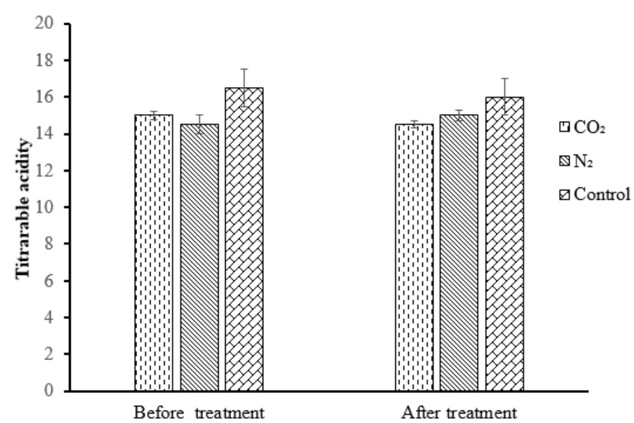

Figure 4: Change of titratable acidity value of initial and 60 days stored dehydrated jack fruit samples after MA treatments maintained at 27 ± 2 °C temperature and 75 ± 5% RH. Lines on the vertical bars represent standard error of the mean.

F. Microbial Analysis

Total aerobic microbial load before and 60 days after either with 99% N_2 or 99% CO_2 treatments showed significant difference ($p<0.05$) but control samples group did not show

Table I: Changes of L*, a* and b* values of initial and 60 days stored dehydrated jack fruit samples after MA treatments maintained at 27 ± 2 °C temperature and 75 ± 5% RH.

Treatment	L* value		a* value		b* value	
	Before treatment	After treatment	Before treatment	After treatment	Before treatment	After treatment
99% N_2 treatment	47.92±4.37^{aA*}	44.38±5.44^{aA}	11.82±1.99^{aB}	12.89±2.59^{aB}	41.42±4.34^{aC}	35.38±3.24^{aD}
99% CO_2 treatment	45.03±4.30^{aA}	43.16±2.55^{aA}	14.03±1.84^{aB}	15.33±1.63^{aB}	37.45±4.20^{aC}	36.09±2.76^{aC}
Control	46.93±3.70^{aA}	44.24±3.52^{aA}	13.06±1.93^{aB}	16.91±1.65^{aB}	38.93±4.14^{aC}	34.80±2.79^{aC}

*Means± SD values followed by same superscripted small letters in the same column and Means± SD values in the same row with same superscripted capital letters are not significantly different (p>0.05).

any significant difference (p>0.05) during the study (Figure 5). Yeast and mold load before and 60 days after 99% N_2 and 99% CO_2 gas treatment showed significant difference (p<0.05) compare to the initial sample. But control sample did not show any significant difference (p>0.05) during the study (Figure 6). According to the results of yeast and mold and aerobic microbial counts in both 99% N_2 and 99% CO_2 gas treated samples indicated that, considerable reduction of microbial load occurred within MA treated samples compared to the control samples. The yeast, mold and bacterial count of osmo-dehydrated papaya fruit samples shown resistance to the microbial growth under MAP (Rodrigues *et al*., 2006).

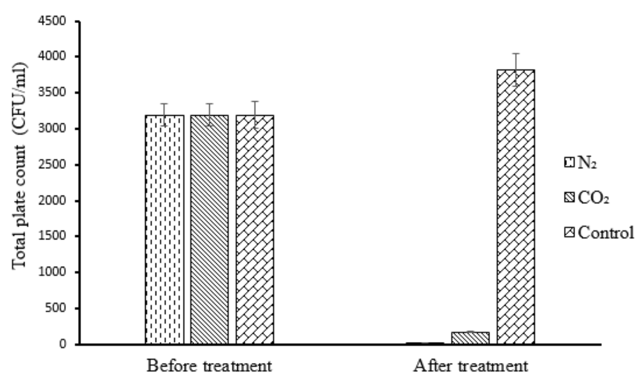

Figure 5: Change of aerobic microbial load of initial and 60 days stored dehydrated jack fruit samples after MA treatments maintained at 27 ± 2 °C temperature and 75 ± 5% RH. Lines on the vertical bars represent standard error of the mean.

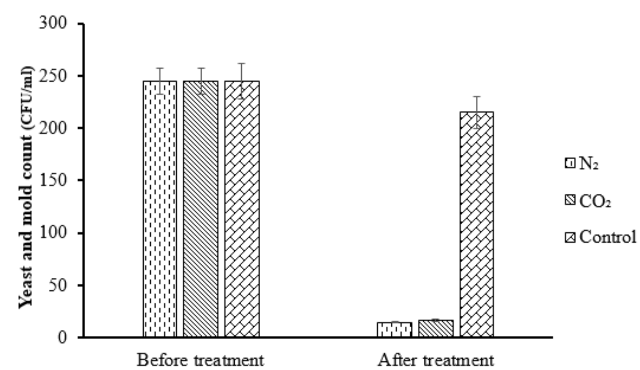

Figure 6: Change of yeast and mold counts of initial and 60 days stored dehydrated jack fruit samples after MA treatments maintained at 27 ± 2 °C temperature and 75 ± 5% RH. Lines on the vertical bars represent standard error of the mean.

IV. Discussion

The L* value represent the lightness of the sample, where 100 represent white and zero represents black. The a* value designates redness when positive or greenness when negative. The b* value indicates yellowness when positive or blueness when negative (Pathare *et al*., 2013). Higher temperatures, presence of light and oxygen accelerate the reduction of the L* and b* values at the same time increases the a* value, resulting in a gradual darkening of the product during storage which may be result to browning reactions due to phenol oxidation (Fu *et al*., 2017).

Jackfruits are rich in carotenoids, producing golden yellowish color to the mature jackfruit. Carotenoids are highly susceptible to oxidative deterioration (Saxena *et al*., 2009). The jackfruit sample before and after treated with 99% N_2 gas shown significant change in b* value (yellowness) whereas L* and a* values remained unchanged. This is may be due to gradual oxidation of carotenoids pigments (Rodriguez-Amaya, 1999; Saxena *et al*., 2009) of dehydrated jackfruit samples during storage. The carotenoids oxidation may be resulted due to the residual oxygen (Caicedo *et al*., 2007) remaining in the 99% N_2 gas. Similarly, N_2 gas may have high residual moisture content which may have absorbed by the dehydrated jackfruit samples during the storage.

In general, phenolic enzymatic reactions taken place to form oxidized forms of phenolics, which further polymerize to form brown pigments during drying, storage, and distribution (Perera, 2005). Other chemical reactions also that can occur during drying and storage are Maillard reaction, caramelization, and ascorbic acid browning (Perera, 2005). The L*, a* and b* values of 99% CO_2 gas treated dehydrated jack fruit samples and L* and a*values of 99% N_2 treatment did not change during the study. This is may be due to the deficiency of O_2 needed for phenol oxidation in jackfruit samples. The amount of O_2 needed for phenolic oxidation to take place may have replaced by CO_2 and N_2 gases. Therefore, browning reaction of dehydrated jackfruit samples can be prevented by either usage of 99% CO_2 or N_2 gas as MA treatments.

The aim of MAP is to exhaust the air inside the packaging and create vacuum or replace the air with a mixture of gases which can control the unfavourable changes of the package foods (Mozhdehi *et al*., 2017). The result of this study showed that moisture content in 99% CO_2 treated dehydrated jackfruit samples did not change during the storage. The MA treatment prevents samples from contact to the ambient environment, consequently moisture absorption of food reduced during the storage. However, the moisture content of the dehydrated jackfruit samples had increased 60 days after storage in the 99% of N_2 treatment. This moisture increase may occur due to the high residual moisture in the 99% N_2 gas treatment.

Maintaining the quality of a food product during modified atmospheric storage is mainly due to the inhibition of growth of spoilage microorganisms (Rodrigues *et al*., 2006). During the hermetic storage period, molds and oxidative yeasts metabolize the organic acids resulting decrease in pH (Sperber *et al*., 2009). The result of this study showed that pH of the jackfruit samples did not changed. The inhibition of microbial growth in samples due to the MA storage may prevent production of organic acids (Odeyemi *et al*., 2020). Therefore, pH of the sample could remain unchanged due to control of initial microorganism load in the N_2 or CO_2 treated samples.

Microorganisms degrade substrates by fermentation (Odeyemi *et al*., 2020) and enzymatic hydrolysis (Shafiei *et al*., 2010) during the storage that leads to increase of total acids in the stored foods. The acidity of hermetically stored dehydrated jackfruit increases gradually as a result of acid hydrolysis. Bacteria like *Pseudomonas fluorescens* spp., *Streptomyces lividans, Thermobifida fusca, Cellulomonas fimi* and fungus like *Aspergillus oryzae, Trichoderma reesei*, and *Phanerochaete chrysosporium* are efficient degraders of starch, chitin, and the polysaccharides in plant cell walls (Lynd *et al*., 2002). But modified atmospheric condition inhibits the microbial growth (Odeyemi *et al*., 2020) on the dehydrated jackfruit samples. Therefore, the results showed that titratable acidity of dehydrated jackfruit samples did not change due to control of initial microorganism load in the 99% N_2 or CO_2 treated sample.

Prolonged storage period of foods leads to reduce in both the total as well as reducing sugars. This might be attributed due to the breakdown of polysaccharides into monosaccharaides as a result of acid hydrolysis (Odeyemi *et al*., 2020). Brix value increases with the increment of soluble solids of the sample. According to the results, MA condition increases the total soluble solids of the samples. Therefore, it may be hypothesized that N_2 and CO_2 gas accelerate the acid hydrolysis of the dehydrated jack fruit samples.

Bacteriostatic and fungistatic effects of MA condition achieved by expel of atmospheric oxygen needed for microbial growth (Odeyemi *et al*., 2020). Generally, the inhibitory effect of microorganism due to increases in the lag phase and generation time during the logarithmic phase (Bertrand, 2019). Atmosphere containing less than 1% oxygen could inhibit growth of storage fungi (Opara *et al*., 2019). The modified atmosphere storage studies on peanut resulted that modified atmosphere condition suppress the aflatoxin production (Opio *et al*., 2018). Antimicrobial activity of CO_2 is a result of the gas being absorbed onto the surface of the food forming carbonic acid, subsequent ionization of the carbonic acid and a reduction in pH (Yu and Chen, 2019).

There are many theories regarding the way in which CO_2 act as a bacteriostatic and fungistatic. Such are, CO_2 gas affects the cell membrane function including effects on nutrient uptake and absorption of microorganisms and CO_2 gas inhibits of enzymes or decreases in the rate of enzyme reactions (Farber, 1991). The CO_2 gas penetrates through bacterial membranes, leading to intracellular pH changes. And also, CO_2 directly changes the physico-chemical properties of proteins (Farber, 1991). Similarly, Nitrogen gas is considered as an inert gas which acts as little or no antimicrobial activity on its own due to its low solubility in water (Farber, 1991). But anti-microbial effects of N_2 mainly achieved through expel of atmosphere O_2 gas from the package and prevent packages from collapse.

V. Conclusions

The study revealed that color, moisture content, pH and titratable acidity values are not changed except brix value and microbial population during the 60 days of MA storage either using 99% CO_2 or 99% N_2 gas treatments. Contrast to the hermetic storage, MA stored jackfruit samples preserved quality characteristics better. Since, the both inert gasses have the same effect on the quality preservation of dehydrated jackfruit under MA storage conditions. Since, the modified atmospheric storage quality preservation of dried jackfruit is comparably higher than hermetic storage.

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