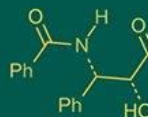


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Shelf stability and quality retention of osmotically dehydrated pineapple as influenced by packaging materials

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Abstract

Packaging plays a decisive role in preserving the quality and extending the shelf life of dehydrated fruit products. The present investigation was undertaken to study the influence of different packaging materials on the physicochemical and nutritional quality of osmotically dehydrated pineapple (*Ananas comosus* L.) cubes during ambient storage. Pineapple cubes were osmotically dehydrated in sucrose syrup, dried, packed in aluminium laminated polyethylene (ALP) and high-density polyethylene (HDPE) pouches, and stored for four months. Changes in total soluble solids, sugars, acidity, pH, ascorbic acid, and moisture content were evaluated at monthly intervals. Results revealed that quality parameters gradually deteriorated during storage; however, ALP packaging significantly minimized these losses. The study confirms the superiority of aluminium laminated polyethylene in maintaining quality and shelf stability of osmotically dehydrated pineapple during ambient storage.

Keywords: Pineapple, osmotic dehydration, packaging materials, shelf life, storage

1. Introduction

Fruits and vegetables constitute an essential component of the human diet owing to their rich content of carbohydrates, organic acids, vitamins, minerals, antioxidants, and dietary fibre. Regular consumption of fruits is associated with reduced risk of chronic diseases and improved nutritional security. However, the highly perishable nature of fruits, coupled with inadequate post-harvest infrastructure, results in considerable quantitative and qualitative losses, particularly in tropical and subtropical regions. Processing and preservation technologies therefore play a crucial role in minimizing post-harvest losses, stabilizing seasonal surpluses, and enhancing the economic value of horticultural produce.

Pineapple (*Ananas comosus* (L.) Merr.) is one of the most important tropical fruits cultivated worldwide and occupies a prominent position in the global fruit processing industry. It is widely appreciated for its pleasant flavour, attractive aroma, juiciness, and balanced sugar-acid ratio. Pineapple is also a rich source of vitamin C, phenolic compounds, and the proteolytic enzyme bromelain, which contributes to its nutritional and therapeutic significance. India is among the major pineapple-producing countries, with cultivation concentrated in states such as West Bengal, Assam, Kerala, Karnataka, Tripura, and parts of the North-Eastern region. Despite its commercial importance, pineapple suffers from high post-harvest losses due to its high moisture content, rapid physiological deterioration, and limited shelf life under ambient conditions.

Drying is one of the oldest and most widely used preservation techniques for fruits, as it reduces water activity, inhibits microbial growth, and extends shelf life. Conventional hot air drying, although simple and economical, often leads to undesirable changes such as excessive shrinkage, loss of colour, flavour degradation, textural hardening, and destruction of heat-sensitive nutrients like ascorbic acid. These quality deteriorations limit consumer acceptance of conventionally dried fruit products and necessitate the development of improved drying strategies.

Osmotic dehydration has emerged as an effective pre-treatment technique to overcome many of the limitations associated with conventional drying. It involves the partial removal of water from plant tissues by immersion in a hypertonic solution, usually containing sugar or

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salt, resulting in simultaneous water loss and solute gain due to osmotic pressure differences. Unlike direct thermal drying, osmotic dehydration operates at low temperatures, thereby minimizing thermal damage, preserving colour and flavour, and improving textural characteristics of the final product. Furthermore, osmotic dehydration reduces drying time and energy requirements during subsequent dehydration steps.

Several researchers have reported the successful application of osmotic dehydration in fruits such as pineapple, mango, apple, aonla, and carrot, highlighting its ability to improve sensory quality and retention of nutrients. The efficiency of osmotic dehydration is influenced by multiple factors, including osmotic agent concentration, temperature, immersion time, fruit geometry, and the ratio of fruit to osmotic solution. Among these, sucrose concentration plays a critical role in determining mass transfer kinetics, dehydration yield, and quality attributes of the osmo-treated product.

Although osmotic dehydration significantly improves the initial quality of dried fruit products, it does not produce a microbiologically stable product by itself. Therefore, osmosed fruits require further drying and appropriate packaging to ensure storage stability. The hygroscopic nature of osmotically dehydrated products makes them highly susceptible to moisture absorption during storage, which can adversely affect physicochemical properties, nutritional quality, and sensory acceptability (Paul *et al.*, 2012) [1]. Hence, packaging assumes a pivotal role in maintaining the quality of dehydrated fruits during storage.

Packaging materials differ widely in their barrier properties against moisture, oxygen, and light, all of which influence the shelf life of dried fruit products. High-density polyethylene (HDPE) is commonly used due to its low cost and good mechanical strength; however, its relatively high water vapour transmission rate can lead to moisture ingress during storage. In contrast, aluminium laminated polyethylene offers superior barrier properties, effectively restricting moisture and oxygen permeability and thereby enhancing product stability (Paul *et al.*, 2012) [1]. Several studies have demonstrated the superiority of laminated packaging materials over conventional plastic films in preserving quality attributes of dehydrated fruits such as apple, mango, pineapple, and aonla.

Despite the availability of literature on osmotic dehydration and packaging of fruits, comprehensive studies integrating osmotic concentration, drying method, and packaging material and their combined influence on storage stability of dehydrated pineapple cubes are limited. Most existing studies focus either on process optimization or on packaging effects alone, with limited emphasis on their interactive impact on physicochemical and nutritional changes during storage. Understanding these interactions is essential for developing commercially viable processing protocols that ensure extended shelf life without compromising product quality.

Therefore, the present investigation was undertaken to evaluate the effect of osmotic dehydration parameters and packaging materials on the quality retention of dehydrated pineapple cubes during ambient storage. The study aims to generate scientific information that can contribute to value addition, reduction of post-harvest losses, and development of shelf-stable pineapple products suitable for small-and medium-scale processing industries.

2. Materials and Methods

Mature pineapple fruits (cv. Queen) were washed, peeled, cored, and cut into uniform cubes. The cubes were steam blanched briefly and subjected to osmotic dehydration in sucrose syrup (fruit:syrup ratio 1:2) with permitted preservatives. Osmosed cubes were dried at 60 °C until constant weight was attained.

Based on preliminary quality evaluation, selected treatments were packed in:

- Aluminium laminated polyethylene (200 gauge)
- High-density polyethylene (200 gauge)

The samples were sealed and stored at ambient temperature for four months. Observations on total soluble solids (°Brix), reducing sugars (%), non-reducing sugars (%), total sugars (%), acidity (%), pH, ascorbic acid (mg 100 g⁻¹), and moisture content (%) were recorded at monthly intervals. The experiment was laid out in a completely randomized design with four replications, and data were statistically analyzed.

3. Results and Discussion

3.1 Total Soluble Solids (TSS)

Total soluble solids of osmotically dehydrated pineapple cubes decreased progressively during ambient storage irrespective of packaging material (Table 1). In aluminium laminated polyethylene (ALP) packages, TSS decreased from 74.49 to 72.80 °Brix after four months, whereas HDPE-packed samples showed a reduction from 73.24 to 72.44 °Brix. The reduction in TSS during storage may be attributed to moisture absorption and dilution of soluble solids, a common phenomenon reported in osmotically dehydrated fruit products (Paul *et al.*, 2012) [1]. Superior retention of TSS in ALP-packed samples may be due to its lower water vapour transmission rate.

3.2 Reducing Sugars

Reducing sugar content increased steadily with storage duration in both packaging materials (Table 2). ALP-packed samples recorded an increase from 33.35% to 39.79%, while HDPE-packed samples showed an increase from 32.61% to 38.53% after four months of storage. The increase in reducing sugars may be attributed to the hydrolysis of non-reducing sugars under acidic conditions during storage, as earlier reported for osmotically dehydrated fruits (Ponting, 1966; Yadav and Singh, 2012) [10, 2]. Similar trends were observed in osmo-dehydrated pineapple and guava products.

3.3 Non-Reducing Sugars

A continuous decline in non-reducing sugars was observed throughout the storage period in both packaging materials (Table 3). In ALP-packed samples, non-reducing sugars decreased from 39.83% to 29.62%, whereas in HDPE-packed samples the reduction was from 39.40% to 28.83%. The decline in non-reducing sugars may be attributed to their conversion into reducing sugars through hydrolytic reactions during storage, as reported by Torreggiani (1993) [7] and Raoult-Wack (1994) [8]. Better retention of non-reducing sugars in ALP packaging may be due to reduced moisture ingress and oxidative reactions.

3.4 Total Sugars

Total sugar content showed a gradual decline during storage irrespective of packaging material (Table 4). Total sugars

decreased from 72.75% to 68.62% in ALP-packed samples and from 72.44% to 68.15% in HDPE-packed samples after four months of storage. The reduction in total sugars may be attributed to moisture absorption and subsequent dilution effects, as well as biochemical transformations occurring during storage (Paul *et al.*, 2012) [1]. Aluminium laminated polyethylene packaging helped in better retention of total sugars due to its superior barrier properties.

3.5 Titratable Acidity

Titrate acidity of osmotically dehydrated pineapple cubes decreased progressively during ambient storage (Table 5). At the end of storage, acidity declined to 1.25% in both ALP and HDPE packages. The decrease in acidity may be due to degradation of organic acids and their interaction with sugars during storage. Similar reductions in acidity during storage of osmotically dehydrated fruit products have been reported by Kannan and Thirumaran (2002) [6].

3.6 pH

The pH of dehydrated pineapple cubes increased gradually during storage, exhibiting an inverse relationship with titratable acidity (Table 5). After four months, pH values increased to 3.77 in ALP-packed samples and 3.63 in HDPE-packed samples. The increase in pH may be attributed to the reduction in organic acid content during storage, as earlier observed in dehydrated fruit systems (Torreggiani, 1993; Yadav and Singh, 2012) [7, 2].

3.7 Ascorbic Acid

Ascorbic acid content decreased significantly during storage in all treatments (Table 6). ALP-packed samples showed a reduction from 26.04 to 18.34 mg 100 g⁻¹, while HDPE-packed samples recorded a decrease from 24.15 to 17.44 mg 100 g⁻¹ over four months. Loss of ascorbic acid may be attributed to oxidative degradation and sensitivity of vitamin C to oxygen and moisture during storage (Dennison and Kirk, 1978) [5]. Lower losses observed in ALP packaging may be due to its reduced oxygen permeability, as also reported by Paul *et al.* (2012) [1].

3.8 Moisture Content

Moisture content increased progressively during storage in both packaging materials (Table 7). ALP-packed samples showed an increase from 12.41% to 13.90%, whereas HDPE-packed samples exhibited a higher increase from 12.64% to 14.23%. The higher moisture gain in HDPE-packed samples may be attributed to its higher water vapour transmission rate compared to aluminium laminated polyethylene. Similar observations were reported in osmotically dehydrated fruit products by Yadav and Singh (2012) [2].

Table 1: Changes in total soluble solids (°Brix) of osmotically dehydrated pineapple during ambient storage

Packaging material	1 month	2 months	3 months	4 months
ALP	74.49	74.43	73.90	72.80
HDPE	73.24	72.52	73.25	72.44

Table 2: Changes in reducing sugars (%) of osmotically dehydrated pineapple during ambient storage

Packaging material	1 month	2 months	3 months	4 months
ALP	33.35	35.25	34.16	39.79
HDPE	32.61	34.63	35.33	38.53

Table 3: Changes in non-reducing sugars (%) of osmotically dehydrated pineapple during ambient storage

Packaging material	1 month	2 months	3 months	4 months
ALP	39.83	36.65	36.32	29.62
HDPE	39.40	36.52	34.99	28.83

Table 4: Changes in total sugars (%) of osmotically dehydrated pineapple during ambient storage

Packaging material	1 month	2 months	3 months	4 months
ALP	72.75	71.58	70.81	68.62
HDPE	72.44	71.16	70.32	68.15

Table 5: Changes in titratable acidity (%) and pH of osmotically dehydrated pineapple during ambient storage (4th month)

Packaging material	Acidity (%)	pH
ALP	1.25	3.77
HDPE	1.25	3.63

Table 6: Changes in ascorbic acid content (mg 100 g⁻¹) of osmotically dehydrated pineapple during ambient storage

Packaging material	1 month	2 months	3 months	4 months
ALP	26.04	23.36	21.63	18.34
HDPE	24.15	21.75	19.65	17.44

Table 7: Changes in moisture content (%) of osmotically dehydrated pineapple during ambient storage

Packaging material	1 month	2 months	3 months	4 months
ALP	12.41	13.18	13.22	13.90
HDPE	12.64	13.92	13.57	14.23

4. Conclusion

The study clearly demonstrates that packaging material significantly influences shelf life and quality of osmotically dehydrated pineapple. Aluminium laminated polyethylene proved superior to HDPE in preserving physicochemical and nutritional attributes during ambient storage.

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