Influence of Osmotic Pre-treatment and Drying on Physicochemical, Microbial, 
and Storage Stability of African Star Apple

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Abstract- African star apple (Chrysophyllum albidum) is a highly nutritious fruit rich in vitamins A, B, and C. However, African star apple (ASA) is still an underutilized fruit due to high post-harvest losses. The fruit has not been processed into a stable shelf product. The aim of this study was to determine the chemical composition and storage stability of osmotically dried ASA. Fresh matured ASA was sliced into 5 mm thickness and immersed in different concentrations of sugar solution (50, 55, and 60 °Brix) for 24 h prior to drying in a cabinet dryer (55 °C, 18h). The products were stored for 8 weeks and samples were taken at 2 weeks intervals for proximate composition, microbiological, and vitamin analysis. Colour measurement and sensory attributes of the osmotically dried ASA were also determined. The proximate composition of the sample showed that there was no significant reduction in the proximate contents of the samples treated with different osmotic sugar solutions after 8 weeks of storage. However, there was a slight reduction in vitamin A (314.23 - 293.30 µg/100 g), C (11.94 – 7.38 mg/100 g), and E (8.32 – 5.15 mg/100 g) contents of fruit after 8 weeks of storage. The microbial load of the sample decreased with increased °Brix level while colour intensity and sensory properties increased with an increase in °Brix level of the osmotic solution. This study provides basic information for postharvest management of ASA to boost its economic importance.

Keywords- African Star Apple, Osmotic Dehydration, Proximate Composition, Vitamin Analysis, Sensory Properties.

1 INTRODUCTION

African star apple (Chrysophyllum albidum) is a tropical fruit commonly grown and consumed in the West, East and Central Africa. In Southern Nigeria, the fruit is known by various local names: “agbalumo” by Yorubas, “udara” by Igbos and “agwaluma” by Hausas (Amusa et al., 2003). African star apple (ASA) is rich in vitamins and minerals (Chukwuemeke, 2006) in addition to antioxidants, total phenols and flavonoids (Oloyede and Oloyede, 2014). These natural antioxidants can prevent degenerative diseases such as cancer and coronary heart diseases (Okoli and Okere, 2010). Despite high nutritional composition of ASA, it is prone to high post-harvest losses. More than 30% of post-harvest losses of ASA have been reported. Losses are due to poor post-harvest handling practices, and lack of proper processing and preservation techniques (Amusa et al., 2003).

Osmotic dehydration is a pre-treatment used before drying. This process naturally occurs when fruits and vegetables are placed in a hypertonic sugar or salt solution, the fruits or vegetable develops high osmotic pressure and low water activity (Yucel et al., 2010), leading to a reduction in microbial attack. Osmotic dehydration process can be used for the development of new fruit and vegetable products because of its ability to improve the sensorial and nutritional properties of fresh products (Corrêa et al., 2010). In addition, it increases the sugar to acid ratio of fruits and improves their texture and pigments stability during dehydration and storage (Landim et al., 2016). Osmotic dehydration is less energy-intensive than air or vacuum drying since it can be conducted at low or ambient temperature (Chavan and Amarowicz, 2012). In a bid to reduce post-harvest losses of ASA, past research investigated the effect of different pre-treatments methods (blanching, lime juice, ascorbic acid and salt solution) on the colour and ascorbic acid contents of dried ASA (Komolafe et al., 2019).

This study aimed to produce ready-to-consume ASA flakes. The objectives were to determine the physicochemical composition, storage stability and acceptability of dried ASA flakes.

2 MATERIALS AND METHODS

African star apple (ASA) and sugar were procured from Odo obaa market in Ogbomoso, South West, Nigeria. Vitamin A, B, and C were purchased from Nice Chemicals PVT, Ltd., Kerala, India.

2.1 PREPARATION OF OSMOTICALLY DRIED AFRICAN STAR APPLE FLAKE

Osmotic dehydration of ASA was done using the method described by Ela et al. (2015), with some modifications. Briefly, the fruit was washed, de-seeded, peeled and the pulp was cut into slices of 5 mm thickness. Osmotic solution of 50 °Brix, 55 °Brix and 60 °Brix were prepared by dissolving 50 g, 55 g and 60 g of sugar in 50 ml, 45 ml and 40 ml warm distilled water (50 °C), respectively. The Brix level of the osmotic solutions were confirmed using a hand-held refractometer (Bellingham + Stanley Ltd, Kent, England).

The ASA slices (500 g) were immersed in the osmotic solution (50 °Brix, 55 °Brix, and 60 °Brix) at ambient temperature (30 ± 2 °C) for 24 h. The weight ratio of the osmotic medium to fruit samples was 2:1. After 24h of treatment, the samples were weighed and rinsed in clean water to remove excess solution on the surface and dried in cabinet dryer at 55 °C for 18 h, packaged in low-density polyethylene (zip locked airtight) bags.

2.2 DETERMINATION OF PROXIMATE COMPOSITION OF DRIED AFRICAN STAR APPLE FLAKES

The proximate composition (protein, crude fat, ash, crude fibre and moisture) of the osmotically dried and untreated ASA was determined according to AOAC (2010). Prior to analyses, the dried fruits pulp was ground.
into powder. Carbohydrate content was determined by difference (AOAC, 2010) using the formula:

\[ \text{100} - (\% \text{protein} + \% \text{crude fat} + \% \text{ash} + \% \text{crude fibre} + \% \text{moisture}) \]

### 2.3 VITAMINS ANALYSES

#### 2.3.1 Vitamin A

Vitamin A contents of the osmotically dried ASA was determined by the procedure described by Ela et al. (2015). About 5 g of sample was ground and dissolved in 15 mL acetone with the addition of a few crystals of anhydrous sodium sulphate. The vitamin was extracted with the reagents three times by continuous filtering of the solution into a beaker. The filtrate was transferred into a separating funnel, and 10 mL petroleum ether was added and mixed thoroughly. Two distinct layers were separated out on standing. The lower layer was discarded while the upper layer was collected in a 100 mL volumetric flask and the volume was made up to 100 mL with petroleum ether. The optical density of the solution determined at 452nm was recorded. The concentration of \( \beta \)-carotene (vitamin A precursor) and vitamin A were estimated using equation (1) and (2), respectively.

\[
\beta - \text{carotene} = \frac{\text{OD} \times 13.9 \times 10000 \times 100}{\text{Weight of sample} \times 550 \times 1000} \quad (1)
\]

\[
\text{Vitamin A} = \frac{\beta - \text{carotene (ug/100)}}{0.6} \quad (2)
\]

#### 2.3.2 Vitamin C

Vitamin C content of the dried ASA was determined spectrometrically according to the procedure described by Rahman et al. (2012). Each sample (1g) was weighed into separate test tubes and ascorbic acid was pipetted into a separate test tube as standard. Trichloroacetic Acid (TCA) solution (1 mL) used as blank was also dispensed into a separate test tube. TCA solutions (10 mL) and Dinitrophenyl hydrazine-thiourea-copper sulphate reagent (1 mL) was added to all the sample test tubes. The tubes were incubated in a water bath at 37 °C for 3 h. The samples were cooled for 10 min in an ice bath with shaking slowly. Two millilitres of cold 12M sulphuric acid was added to all the test tubes. A spectrophotometer was adjusted with the blank to read zero absorbance at 520 nm. The absorbance of standard and test samples was determined. The concentrations of vitamin C in the samples were estimated using standard curve of vitamin C (Nice Chemicals PVT, Ltd., Kerala, India) and results were expressed as milligram of vitamin C per 100 grams of sample.

#### 2.3.3 Vitamin E

Vitamin E content of the dried ASA was determined as described by Adepoju et al. (2012). The sample (1g) was placed into a 250 mL conical flask fitted with a reflux condenser wrapped in aluminium foil, and refluxed with 10 mL of absolute alcohol and 20 mL of 1 M sulphuric acid for 45 min. The resultant solution was cooled for 5 min, followed by addition of 50 mL of distilled water and then transferred into a separating funnel covered with aluminium foils. The un-saponifiable matter in the mixture was extracted five times with 50 mL diethyl ether. The combined extract was washed free of acid and the extract was evaporated at a low temperature and the residue obtained was immediately dissolved in 10 mL absolute alcohol. Aliquots of solutions of the sample and vitamin E standard were transferred to a 20 mL volumetric flask, 5 mL absolute alcohol was added, followed by a careful addition of 1 mL concentrated HNO3. The mixture was placed in a water bath at 90 °C for 30 mins (i.e. from the time the alcohol begins to boil). Rapid cooling under running water followed and the absorbance of the sample’s solution were read at 470 nm. The concentrations of vitamin E in the samples were estimated using a standard curve of vitamin E (Nice Chemicals PVT, Ltd., Kerala, India) and results were expressed as milligram of vitamin E per 100 grams of sample.

### 2.4 MICROBIOLOGICAL ANALYSIS

The total viable counts of the untreated and the osmotically dried and stored ASA were evaluated as described by Ntuli et al. (2017) with some modifications. Each sample was ground and soaked in distilled water. Serial dilution was performed with 6 test tubes, for each of the four samples using the pour plate method. An aliquot of 1 mL mixture of the 5th and 6th test tubes were firstly poured into the petri dish after the addition of nutrient agar (NEOGEN culture media, Heywood, United Kingdom). The mixture was gently swirl in a circular manner. The plates were allowed to solidify, inverted, and incubated at 37°C for 24 h.

### 2.5 COLOUR MEASUREMENT

The surface colour of dried ASA flakes was determined by placing a chromameter (CR-410, Konica Minolta, Japan) on each sample. The readings were displayed as L* (lightness), a* (redness and greenness) and b* (yellowness and blueness). Colour measurements were done at three different points on the sample surface.

### 2.6 SENSORY EVALUATION

Sensory evaluation was carried out by thirty semi-trained panellists comprising of students and staff of Food Science and Engineering Department, LAUTECH. Testing was done in the sensory laboratory. Each panellist was served with four different samples of osmotically dried ASA flake. The samples were placed in a white plate coded with a three-digit number before to testing. Water was provided for rinsing mouth in-between tasting of each sample. The Panellists were requested to evaluate the colour, taste, flavour, texture and overall acceptance of the product using 7-point hedonic scale with 1 = dislike very much and 7 = like very much.

### 2.7 STATISTICAL ANALYSIS

SPSS software packaged version 16.0 (SPSS Inc., USA) was used for statistical analysis. All data obtained were subjected to analysis of variance (ANOVA) and means were separated using Duncan Multiple Range (DMR) test with significance level determined at p<0.05.
3 Results and Discussion

3.1 Proximate Composition of Osmotically Dried and Stored African Star Apple Flakes

The results of the proximate composition of the dried ASA flakes are presented in Table 1. Generally, there were no significant differences in almost all the proximate parameters (protein, ash, crude fibre, crude protein and carbohydrate) except for moisture content. The protein contents of the dried ASA flakes slightly decreased from 4.25 to 2.91% after 8 weeks of storage. The sample treated with 60 °Brix recorded the least protein content (2.91%), while the untreated sample had the highest content of protein (4.25%). This could be due to the formation of complex compound from free amino acid in the protein and sugar molecules through Maillard reaction, leading to unavailability of protein for quantitative measurement. This observation is in congruent with the findings of Alam et al. (2018) who also reported a decrease in protein content of ginger candy as the storage period advanced. Although there were no significant differences (p<0.05) in the ash contents of all the ASA flakes during the 8 weeks’ storage period, the ash content of the osmotically dehydrated samples was higher (2.56 – 3.05%) than that of the untreated sample (2.47%). This could be due to the presence of added sugar in the osmotically dried ASA. This finding is in agreement with the report of Ela et al. (2015), who also reported a higher ash contents for osmotically dried pawpaw treated with high concentration of an osmotic solution (60 °Brix). Priyanka et al. (2018), also reported increased in ash content of osmo-solar-dried banana after 60 days of storage at ambient temperature.

| Sample                  | Protein (%) | Ash (%) | Crude Fibre (%) | Crude Fat (%) | Moisture (%) | Carbohydrate (%) |
|-------------------------|-------------|---------|----------------|--------------|--------------|------------------|
| **Week 2**              |             |         |                |              |              |                  |
| Untreated sample        | 4.25a       | 2.47a   | 5.34a          | 3.92a        | 8.97c        | 75.05a           |
| 50 °Brix sample         | 3.89a       | 2.56a   | 5.16a          | 3.35a        | 7.88b        | 76.86a           |
| 55 °Brix sample         | 3.52a       | 2.63a   | 5.09a          | 3.15a        | 8.44ab       | 77.21a           |
| 60 °Brix sample         | 3.41a       | 2.64a   | 4.92a          | 3.05a        | 6.32a        | 79.66a           |
| **Week 4**              |             |         |                |              |              |                  |
| Untreated sample        | 4.10a       | 2.60a   | 5.18a          | 3.84a        | 9.21c        | 75.06a           |
| 50 °Brix sample         | 3.76a       | 2.68a   | 5.39a          | 3.25a        | 8.06ab       | 76.82a           |
| 55 °Brix sample         | 3.37a       | 2.75a   | 4.95a          | 3.06a        | 8.71c        | 77.14a           |
| 60 °Brix sample         | 3.34a       | 2.71a   | 5.76a          | 2.93a        | 6.45a        | 79.82a           |
| **Week 6**              |             |         |                |              |              |                  |
| Untreated sample        | 4.02a       | 2.66a   | 5.03a          | 3.80a        | 9.46c        | 75.02a           |
| 50 °Brix sample         | 3.68a       | 2.76a   | 5.17a          | 3.22a        | 8.27ab       | 76.89a           |
| 55 °Brix sample         | 3.26a       | 2.82a   | 4.77a          | 2.98a        | 8.96c        | 77.21a           |
| 60 °Brix sample         | 3.22a       | 2.79a   | 5.31a          | 2.87a        | 6.65a        | 79.82a           |
| **Week 8**              |             |         |                |              |              |                  |
| Untreated sample        | 3.73a       | 2.78a   | 4.94a          | 3.58a        | 10.21c       | 74.77a           |
| 50 °Brix sample         | 3.40a       | 2.90a   | 5.02a          | 3.03a        | 9.60c        | 76.52a           |
| 55 °Brix sample         | 3.03a       | 2.94a   | 4.34a          | 2.65a        | 9.12c        | 77.32a           |
| 60 °Brix sample         | 2.91a       | 3.05a   | 4.24a          | 2.51a        | 8.40a        | 78.99a           |

Values with different alphabet(s) along the same column for each week are significantly different (p<0.05).

The crude fibre content of the untreated sample was higher (5.34%) than that of the osmotically treated samples (4.24 – 5.18%). This could be due to the ability of the sugar molecules in the osmotically dried sample to bind and form a complex with some of the water molecules in the flakes, thereby making it less fibrous. Thus, resulting in a decrease in the fibre contents of the dried-stored ASA flakes. Similar findings were reported by Priyanka et al. (2018) for osmo-solar-dried banana stored for 60 days. The fat content of the ASA flakes was decreased as the storage period and osmotic concentration increases. The highest value of fat (3.92%) was recorded for the untreated sample at 2 weeks of storage while the 60 °Brix treated sample had the least fat contents (2.51%) at 8 weeks of storage (Table 1). A previous study also reported lower fat contents for pawpaw slices treated with 60 °Brix compared with those treated with lower concentrations of the osmotic solution (Ela et al., 2015).

The untreated and osmotically treated ASA flakes tend to accumulate moisture during the storage period, with the untreated sample having the highest moisture contents (10.21%) followed by the 50 °Brix treated sample (9.60%) after the storage period (Table 1). This could be due to osmotic dehydration enhances water loss (Fasogbon et al., 2012). The carbohydrate contents of the ASA flakes were increased as the °Brix level and storage period increases (Table 1). This could be due to the use of sugar as an osmotic solution, since sugar is also a source of carbohydrate. In general, the results of the proximate composition of the dried ASA showed that osmotic dehydration and storage period does not significantly affect the proximate contents of the product.

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3.2 VITAMIN A, C, AND E CONTENTS OF OSMOTICALLY DRIED AND STORED AFRICAN STAR APPLE FLAKES

There were no significant changes in the vitamin contents of the untreated and the treated ASA flakes during the first 6 weeks of storage. However, significant decline in all the vitamins was observed at 8 weeks of storage (Table 2). This could be due to the degradation of the vitamins as a result of the extended storage time. Variation in the concentration of the osmotic solution does not have significant adverse effects on the vitamins (Table 2).

Table 2. Vitamin A, C, E Contents and Colour of Osmotically Dried and Stored Africa Star Apple Flakes

| Sample       | Vitamin A (µg/100 g) | Vitamin C (mg/100g) | Vitamin E (mg/100g) | Colour |
|--------------|----------------------|---------------------|---------------------|--------|
|              | Week 2               |                     |                     |        |
| Untreated    |                      |                     |                     |        |
|              | Week 4               |                     |                     |        |
| Untreated    |                      |                     |                     |        |
|              | Week 6               |                     |                     |        |
| Untreated    |                      |                     |                     |        |
|              | Week 8               |                     |                     |        |
| Untreated    |                      |                     |                     |        |

The untreated ASA flake recorded the highest higher vitamin A, C, and E contents compared to the treated samples. This could be due to leaching of the vitamins during the prolong osmotic dehydration process (24 h). According to Phisut and Aekkasak (2013), leaching of natural solutes such as vitamins, phenolic compound and acids into the osmotic solution could occur during osmotic dehydration process. Leaching of the vitamins in washing water can also occur during the removal of surface sugar on osmotically treated samples. Although drying temperature can also affect vitamin losses, the extent depends on the drying method and temperature.

The drying method (cabinet drying) employed in this study increased the rate of water removal from the sample, and the drying temperature (55 °C) is not too high to cause significant vitamin losses. Generally, vitamin C content is used as indicator for vitamin preservation in dried food items because of its heat sensitivity. Thus, if vitamin C is well maintained during drying process, other vitamins are likely to be retained in the dried products (Ali et al., 2016). Cabinet drying has been reported to be a better drying method to minimize losses of vitamin C acid in leaves provided there is no marked increase (> 55 °C) in the temperature of the product (Chauhan et al., 2016). The findings of this study is in congruent with the findings of Kumar et al. (2008), who also reported a gradual decline in β-carotene (pro-vitamin A) contents of osmo-vacuum dehydrated mango slices stored for six months. Similarly, Priyanka et al. (2018) reported decreased in vitamin C contents for stored osmo-dried banana. Decreased in vitamin E contents of the flakes during a prolonged storage period could be due to thermal dehydration and oxidation of the vitamin during the storage period.

3.3 COLOUR CHANGES OF OSMOTICALLY DRIED AND STORED AFRICAN STAR APPLE FLAKES

The colour (lightness, redness and yellowness) of the osmo-dried African star apple increased with an increase in °Brix level and storage period (Table 2). In general, ASA treated with highest sugar solution (60 °Brix) had the highest L* values (27.20 – 27.53) while the untreated sample had the least L* values (23.51 – 23.91) throughout the storage period. Although all the treated samples were not significantly different in terms of their lightness (L*), sample treated with 60 °Brix appeared to be lighter than all the other samples while the untreated sample was darker compared to the treated samples. This might be because of the protection of the treated ASA by the high sugar contents in the fruit cells against direct thermal destruction (Afrin et al., 2016). The redness (a*) and yellowness (b*) values of the treated samples increased with increased in °Brix level and storage period. However, no significance differences (P<0.05) occurred between the redness and yellowness of the treated ASA flakes. On the other hand, the untreated sample recorded lower a* and b* values as storage period increases, with significant differences (P<0.05) in its redness (a*) and yellowness (b*).
yellowness ($b^*$) values compared with that of the treated samples (Table 2). This could be due to stability of pigment during osmotic dehydration (Landim et al., 2016). Mishra et al. (2015) also observed increased in the values of $a^*$ (redness) in osmo-dehydrated and infrared dried papaya slices.

3.4 SENSORY EVALUATION OF OSMOTICALLY DRIED AND STORED AFRICAN STAR APPLE FLAKES

The sensory results of the ASA are presented in Table 3. The untreated ASA was similarly rated with the treated samples in terms of appearance and flavour; however, the treated samples were rated higher than the untreated sample in terms of texture, taste and overall acceptance. ASA sample treated with 60 °Brix sucrose solution was highly rated by the panelist in terms of all the sensory attributes (appearance, flavour, texture, taste and overall acceptance), followed by 55 °Brix and 50 °Brix treated samples while the untreated samples recorded lower sensory scores in all sensory attributes evaluated in this study. Thus, the panelists preferred the 60 °Brix treated sample than other samples. This result indicates that absorbed sugar during osmotic treatments improved the taste and flavour of the treated ASA flakes. In addition, osmotic treatment also helps to retain the colour (appearance) of the treated samples better than the untreated sample as evidence in colour measurement (Table 2) and improve the texture of the dried ASA flakes due to ability of sugar to bind water (humectant) in food. This, causes moisture to be retained for longer period in the dried ASA flakes and improve the texture of the treated samples. However, reactions that needs water are destroyed due to presence of sugar. This is because sugar has the ability to reduce the availability of free water for deterioration reactions (Tiefenbacher, 2019). The ability of osmotic dehydration to improve sensorial properties of fruits has also been reported (Corrêa et al., 2010).

Table 3. Sensory Attributes of Osmotically Dried Africa Star Apple Flakes

| Sample          | Appearance | Flavour | Texture | Taste | Overall Acceptance |
|-----------------|------------|---------|---------|-------|--------------------|
| Untreated sample| 5.60a      | 5.08a   | 4.95a   | 3.92a | 4.88a              |
| 50 °Brix sample | 5.32a      | 5.09a   | 5.20b   | 5.80b | 5.76b              |
| 55 °Brix sample | 5.60a      | 5.16a   | 5.32b   | 6.12b | 5.80b              |
| 60 °Brix sample | 5.88a      | 5.36a   | 5.72b   | 6.32b | 6.16b              |

Values with different alphabet(s) along the same column for each week are significantly different (p<0.05).

3.5 MICROBIAL LOAD OF SAMPLES AS INFLUENCED BY STORAGE PERIOD

Total viable count is a measure of the total number of bacteria that are able to grow in an aerobic environment under moderate temperature (CFS, 2014). It is a measure of the level of hygiene during processing /handling and storage condition. Table 4 presents the total viable counts (TVC) of the osmo-dried and stored ASA flakes. TVC was not detected in the freshly prepared ASA flakes (results not presented) and the treated samples after 2 weeks of storage, however, TVC levels of the treated sample increased with an extended time of storage. This could be due to contamination from the packaging material as a result of dripping from accumulated moisture in the material. This could be possible because the packaged samples were stored at room temperature (30 ± 2 °C) prior to analysis. Alam et al. (2018) also reported increased in microbial load of ginger candy as storage period advanced. The TVC levels of the untreated sample (12 x 10° - 25 x 10⁹) was generally higher than that of the treated dried ASA (12 x 10³ - 15 x 10⁹), with sample treated with 60 °Brix having the least TVC (12 x 10⁴ cfu/g) at 8 weeks of storage. This could be because the high Brix level of the osmotic solution reduces the water activity of the ASA flakes, thus leading to lower microbial contamination. The TVC levels of the treated ASA flakes stored for eight weeks were within the satisfactory TVC levels (<10⁶ cfu/g) for ready-to-eat foods (CFS, 2014).

Table 4. Total Viable Count (cfu/g) of Osmotically Dried and Stored Africa Star Apple Flakes

| Sample          | Week 2 | Week 4 | Week 6 | Week 8 |
|-----------------|--------|--------|--------|--------|
| Untreated sample| 12 x 10⁴ | 12 x 10⁴ | 21 x 10⁴ | 25 x 10⁹ |
| 50 °Brix sample | ND     | 12 x 10⁴ | 14 x 10⁴ | 15 x 10⁴ |
| 55 °Brix sample | ND     | 12 x 10⁴ | 14 x 10⁴ | 15 x 10⁴ |
| 60 °Brix sample | ND     | 10 x 10⁴ | 12 x 10⁴ | 12 x 10⁴ |

ND = Not detected

4 CONCLUSION

This study showed that African star apple can be osmotically dried and stored for up to 8 weeks if treated with 60 °Brix osmotic solution. Osmotic dehydration does not result in significant loss of macro and micronutrients (vitamins) in the ASA flakes. ASA treated with 60 °Brix had the best sensory properties and was highly rated by the panelists in terms of all the tested sensory attributes. Consumption of osmotically dried ASA flakes as snack will improve consumer’s nutrient intake, increase the utilization of ASA in Nigeria where the fruit has not been optimally utilized, and also reduce post-harvest losses of the fruit. ASA flakes can also add flavours to baked products such as cake and bread. Osmotic treatment increased the shelf life of African star apple fruit. This will make the fruit available for consumption during off seasons.

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