Article

Interactions between People and Breadfruit in Hawai‘i: Consumption, Preparation, and Sourcing Patterns

Amber Needham and Noa Lincoln *
Tropical Plant and Soil Sciences, College of Tropical Agriculture and Human Resources, University of Hawai‘i at Mānoa, Honolulu, HI 96822, USA; amberau@hawaii.edu
* Correspondence: nlincollin@hawaii.edu

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Abstract: Traditional crops are often forwarded as a critical means for increasing local food, yet little is understood about their consumption patterns in contemporary food systems. This study utilizes a survey to examine the consumption patterns, preparation methods, sources utilized, and awareness of health benefits of breadfruit (Artocarpus altilis) in Hawai‘i. Results indicated that an average of 13.7 servings of breadfruit per year are eaten by an individual; however, the distribution of consumption follows an exponential curve and 57% of participants only eat it three times per year or less. Approximately one-quarter (22%) of a breadfruit is eaten in one sitting on average, which equates to approximately 71 dry grams. Awareness of health benefits correlated to increased consumption, as did knowledge or preparation methods. While a range of sources were utilized, 71% of people source their fruit from a backyard tree, while only 5% ever obtained fruit from a retail store. Such information is useful in determining the consumptive impacts of intervention programs, such as tree giveaways and consumer education, and to understand how to best facilitate the increased consumption of underutilized crops.

Keywords: Artocarpus altilis; breadfruit; consumption; sourcing; food preparation; health awareness

1. Introduction

Breadfruit (Artocarpus altilis) is a food crop that has great implications for improving food security, supplementing staple foods, and mitigating hunger on a global scale, especially in tropical and subtropical regions [1,2]. Its potential is internationally recognized with breadfruit being among the 35 neglected and underutilized crops identified as important to food security [3,4] and listed as a priority crop by the Global Crop Diversity Trust [5]. As part of the efforts to increase breadfruit cultivation and mitigate hunger on an international scale, breadfruit trees have been distributed to 45 countries around the world as part of the Global Hunger Initiative [6].

In Hawai‘i, breadfruit, or ʻulu in the native language, is both agriculturally and culturally important in the history of the Hawaiian Islands [7]. Traditional Hawaiian landscapes included extensive breadfruit agroforests that produced high yields across broad environmental habitats, with minimal growing requirements. Breadfruit was cultivated in extensive arboricultural systems, in home gardens, and as part of mixed agricultural systems [8], and played a significant role in the agricultural economy of the islands [9]. Due to urbanization of landscapes over time, shifting demographics, and a general transition to processed foods, traditional food systems throughout the island chain have largely been lost [10]. However backyard trees, small-scale production, and “wild” trees still remain [8,11].

Significant efforts have been made to revitalize breadfruit in Hawaiian landscapes and food systems, resulting in an increase of trees at both the household and farm level [11,12]. Such efforts
have included large-scale tree giveaways [13], restoration of traditional agricultural systems [14], a growing local food producing sector [11], and consumer education such as outreach, chef campaigns and festivals [12]. Such initiatives have resulted in significant increases in production at multiple levels including backyard trees, small diversified farm plantings, and larger monocropped and mixed orchards [11,13].

A transition toward local food production is supported in rhetoric, if not action, by Hawai’i’s state initiative to double local food production by 2020. Hawai’i currently produces only about 10% of its food locally, although it does produce about 35% of its fruits and vegetables [15]. The state population of ~1.4 million people accommodates an additional 10 million tourists per year. The vast majority of agricultural production in Hawai’i is for export, with the largest acreage being used for cattle, seed production, macadamia nuts, and coffee, all of which are predominantly exported [16]. An additional 10% of local production results in an estimated $313 million dollars increase in state GDP [17]. Breadfruit, as a culturally relevant and highly productive tree, could become a valuable crop with the ability to address food security in the Hawaiian islands. Currently, breadfruit production in the state is on the order of 500,000 pounds per year; based on trees planted but not yet productive, this number is expected to grow to well over 3 million pounds per year in the coming decade [11]. However, it is unclear how much of the breadfruit production is actually consumed.

Although breadfruit has seen a substantial increase in studies globally in tropical and subtropical areas, a recent review paper indicates that “breadfruit remains a vastly understudied crop and could benefit from a wide range of basic investigations” [6]. One area in which breadfruit has received good attention is in nutrition. The fruit is a substantial source of carbohydrates, fiber, and macronutrients such as potassium, calcium, and magnesium, and a good source of vitamins B and C [1]. The fruit is generally not rich in fats or protein but does consist of high-quality proteins necessary for human nutrition [18,19]. The Ma’afala cultivar in particular is noted to have a significantly greater total amount of essential amino acids than other cultivars and of higher quality than other globally recognized staples like corn, peas, soybean, rice, and potato [18]. Furthermore, the fruit’s low glycemic index and high fiber content may combat lifestyle diseases such as diabetes: a prevalent issue amongst Pacific Islander populations [1]. While the nutritive aspects are influenced by cultivar, fruit maturity, and environment [4,20], breadfruit appears particularly well suited to mitigate hunger in rural areas that may live in poverty [2].

While breadfruit has been examined from ethnographic, agronomic, and postprocessing perspectives, consumption of breadfruit has been scarcely investigated. Only a single study that addresses breadfruit consumption was identified in Trinidad, West Indies [21], and a recent study in Hawai’i examined consumer willingness to pay for breadfruit products [22]. It is important to understand the behavior of breadfruit consumers in order to support the development of the market and keep the crop relevant in the conversations of food security, food sovereignty, and human nutrition. The objective of the current study is to address consumption patterns and characteristics of Hawai’i residents in order to examine the factors that may drive or inhibit consumption. In particular, we explore consumer sourcing, preparation methods, and awareness of health effects. Exploring such questions in an underutilized, and culturally significant crop, provides insights into the role of knowledge and culture in food consumption.

2. Material and Methods

A 10-question survey was created to investigate frequency of consumption, source(s) of breadfruit, method(s) of preparation, awareness of health benefits, and consumer demographics. The survey was deliberately kept simple and brief to encourage broad participation; on average, a respondent spent two to three minutes to complete a survey. Questions were a mix of multiple choice and open-ended responses. The survey was piloted with a student population at the University of Hawai’i at Manoa and refined for clarity and accuracy. The survey was made with SurveyMonkey Inc. (San Mateo, CA) online, and distributed in person (via mobile iPad device) and by e-mail list servers. The survey
was given in-person at public festivals; the online survey was accessible from July to December 2018. The results of in-person administration and online participation showed no significant differences (ANOVA) in any response category and, therefore, combined results are presented.

Data was exported and cleaned in Microsoft Excel 14.0 (Redmond, WA). Open-ended questions were coded into categorical responses for analysis. Statistical analyses were conducted in JMP Pro 14 (Cary, NC). Summary statistics and distributions were examined for all data. Statistical analysis focused on correlation of data to two variables of consumption: amount of breadfruit consumed per serving and number of breadfruit servings consumed per year. For continuous variables, linear regressions were applied; for categorical variables, one-way ANOVA, chi-squared tests, and t-tests were applied. For consideration of the interaction between variable, principle component analyses, cluster analyses using K-means clustering, and a multiple correspondence analysis were applied.

3. Results

3.1. Consumer Demographics

A total of 438 people participated in this survey. Overall demographics match well with state census data, indicating that survey participants generally represented the state population (Table 1) [22]. Of the respondents, the largest representations were Caucasian (59.1%), Asian (39.2%), and native Hawaiian (34.0%) (Table 1): 21.5% of all respondents were of multiethnic backgrounds, which is a suitable value to reflect the State demographics that estimate about 24% of the populous to be two or more ethnicities [23]. Most participants ranged from 20 to 39 years old and 35.6% of all respondents claimed to hold a Bachelor’s degree. O’ahu residents represented the largest percentage of participants at 27.0%, while residents from Hawai’i island, Maui Island, and the continental U.S. each comprised about 20% of the sample size. Other islands and locations represented less than 10% of the whole.

<table>
<thead>
<tr>
<th>Ethnicity (n = 437) *</th>
<th>% Respondents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Native Hawaiian</td>
<td>43.0</td>
</tr>
<tr>
<td>Asian</td>
<td>39.2</td>
</tr>
<tr>
<td>Pacific Islander</td>
<td>10.5</td>
</tr>
<tr>
<td>White/Caucasian</td>
<td>59.1</td>
</tr>
<tr>
<td>Hispanic/Latino</td>
<td>8.0</td>
</tr>
<tr>
<td>Other</td>
<td>9.3</td>
</tr>
<tr>
<td><strong>Multiethnic</strong></td>
<td>21.5</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Age (years, n = 435)</th>
<th>% Respondents</th>
</tr>
</thead>
<tbody>
<tr>
<td>0–19</td>
<td>2.1</td>
</tr>
<tr>
<td>20–39</td>
<td>51.9</td>
</tr>
<tr>
<td>40–59</td>
<td>28.9</td>
</tr>
<tr>
<td>60–79</td>
<td>17.0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Education (n = 436)</th>
<th>% Respondents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Junior high</td>
<td>0.4</td>
</tr>
<tr>
<td>High school diploma</td>
<td>7.6</td>
</tr>
<tr>
<td>Some college, no degree</td>
<td>12.3</td>
</tr>
<tr>
<td>Associate degree</td>
<td>5.5</td>
</tr>
<tr>
<td>Bachelor’s degree</td>
<td>35.6</td>
</tr>
</tbody>
</table>
3.2. Frequency and Quantity of Consumption

Participants were asked to estimate how often they ate breadfruit per week, month, and year. From this, total yearly consumption was estimated as a continuous variable. Overall participants ate an average of 13.7 servings of breadfruit per year; however, the data exhibited a large standard deviation (23.3) and a distribution that closely followed an exponential decline (Figure 1). The results indicate that the large majority (~85%) of consumers eat breadfruit less than 20 times per year and most (~57%) consume breadfruit 3 times per year or less. A few consumers eat breadfruit as a primary staple (up to 155 times per year), which is a large factor in pulling up the mean value. Consumers were also asked to estimate how much breadfruit was eaten in a single sitting. On average, consumers ate approximate one-quarter of a breadfruit per serving (22.5%). The data closely followed a normal distribution, with a maximum reported consumption of 5/8 (62.5%) of an entire fruit (Figure 2).

![Figure 1. Number of servings eaten per year by participants with an exponential curve imposed over the histogram.](image-url)
3.3. Preparation

Participants were allowed to indicate culinary methods used to prepare breadfruit for consumption in an open-ended question. Results were coded into 11 preparation methods (Table 2). The most common cooking methods indicated were steamed (68.5%), baked (57.6%), and fried (52.3%). A number of traditional preparation methods were also reported, including *imu*, *pulehu*, and *poi* (see Table 2 for translations). A linear regression indicated a significant relationship between number of servings consumed per year and total number of preparation methods indicated by a participant ($r^2 0.15$, $p < 0.0001$).

Table 2. Preparation methods and the percent response reported by consumers; multiple answers were allowed.

<table>
<thead>
<tr>
<th>Preparation Method</th>
<th>% Respondents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steamed</td>
<td>68.5</td>
</tr>
<tr>
<td>Baked</td>
<td>57.6</td>
</tr>
<tr>
<td>Fried</td>
<td>52.3</td>
</tr>
<tr>
<td>Imu’d *</td>
<td>14.7</td>
</tr>
<tr>
<td>Processed to flour</td>
<td>13.4</td>
</tr>
<tr>
<td>Boiled</td>
<td>4.6</td>
</tr>
<tr>
<td>Hummus</td>
<td>2.9</td>
</tr>
<tr>
<td>Ripe/Raw</td>
<td>2.5</td>
</tr>
<tr>
<td>Pulehu **/grilled</td>
<td>2.1</td>
</tr>
<tr>
<td>Pickled</td>
<td>2.1</td>
</tr>
<tr>
<td>Poi ***</td>
<td>1.7</td>
</tr>
</tbody>
</table>

* *imu’d = put into traditional underground oven; ** pulehu = places directly on coals and charred; *** poi = cooked and mashed with water to make a paste.

3.4. Fruit Sourcing

Respondents indicated that they obtained fruit from a number of sources (Table 3), including a friend’s or family’s tree (63.2%), farmer’s market (28.6%), their own tree (27.7%), farm-direct (12.7%), restaurants (11.4%), retail store or supplier (6.4%), and wild-picked (5.0%). Respondents were allowed to choose multiple sources if applicable; 41.4% of consumers indicated two or more sources for their breadfruit. When examining the importance of fruit source, tree ownership was the only category
that significantly related to an increase in consumption (ANOVA $r^2 0.18, p < 0.0001$). The increase was substantial, with tree owners eating nearly 400% more breadfruit than non-tree owners (from a mean of 7.9 to 30.6 servings per year). The total number of sources a consumer obtains fruit from was significantly correlated to the amount of breadfruit servings eaten per year ($r^2 0.07, p < 0.0001$).

**Table 3.** Sources of breadfruit for consumption as indicated by consumers; multiple answers were allowed.

<table>
<thead>
<tr>
<th>Source of Breadfruit</th>
<th>% Respondents *</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grown by friend/family</td>
<td>63.2</td>
</tr>
<tr>
<td>Bought at farmer’s market</td>
<td>28.6</td>
</tr>
<tr>
<td>Grown by self</td>
<td>27.7</td>
</tr>
<tr>
<td>Grown by farm</td>
<td>12.7</td>
</tr>
<tr>
<td>Bought at restaurant</td>
<td>11.4</td>
</tr>
<tr>
<td>Bought at supplier/retailer</td>
<td>6.4</td>
</tr>
<tr>
<td>Picked from wild tree</td>
<td>5.0</td>
</tr>
<tr>
<td>Multisource (2+)</td>
<td>41.4</td>
</tr>
</tbody>
</table>

* consumers were allowed to pick multiple sources if applicable.

3.5. Consumer Awareness of Health Benefits

Of the participants, 43.2% indicated awareness of health benefits associated with breadfruit. An open-ended question indicated a range of self-assessed benefits that we categorized into glycemic index (4.3%), nutrition (12.0%), fiber (7.3%), protein (3.4%), and carbohydrates (12.4%). Significantly more breadfruit is eaten per year (ANOVA; $r^2 0.09, p < 0.0001$) in the group that is aware of health benefits compared to those who indicate they are unaware of any specific benefits, associated with a 200% increase (from 7.2 to 15.6 servings per year) in mean annual servings.

3.6. Multivariate Analyses

Principle component analysis including total annual consumption and the three consumer parameters investigated (preparation methods, fruit sourcing, and awareness of health benefits) illuminates the relationship between the parameters. Component 1, which describes 51.9% of the variability, aligns well between all three factors, but graphic representation utilizing Component 2 (21.7%) and Component 3 (21.7%) demonstrates nearly perfectly divergent vectors (Figure A1 in Appendix A). Cluster analysis using the two principal components further demonstrates the importance of awareness of health benefits. With five clusters, the data indicates three groups with awareness of health benefits; all three demonstrate higher levels of annual consumption of breadfruit than the two groups without awareness of health benefits, despite variable levels of fruit sources and preparation methods (Figure A2 in Appendix A). A multiple correspondence analysis was applied to the demographic information (age, education, ethnicity, and location) independently to each of the consumer parameters explored above. However, no clear consumer groups were evident.

4. Discussion

4.1. Consumption per Serving

Our results indicate no correlation between serving size of breadfruit and any variable developed from survey responses, indicating that the amount consumers eat in a single sitting is not influenced by demographics, preparation, sourcing of breadfruit, or awareness of health benefits. This result differs from Roberts-Nkru mátah and Badrie (2005), where an increase in serving size was seen to correlate with frequency of consumption. Average consumption was ~22% of a whole breadfruit, closely
approximating a standard curve. According to the Hawai’i ‘Ulu Producers Cooperative, currently the largest wholesaler of breadfruit in Hawai’i, the two most common breadfruit varieties in Hawai’i are the Hawaiian ‘Ulu and Ma’afala, which weigh on average 1.35–1.8 and 0.9–1.35 kg, respectively (D. Shapiro, pers. comm.). Furthermore, processing, which involves discarding the skin and core, removes 14–34% of the total weight of the fruit. With an average weight of 1360 g and 25% loss (341 g) in processing, this amounts to an average serving size of 224 g wet weight. Applying an average drying ratio of 0.32[4], this equates to 71 dry grams. While this is a crude measurement, it gives an initial estimate of an average serving size portion of breadfruit. The weight of our average serving size is surprisingly similar to the “three slices” weight of 216 wet grams that Roberts-Nkrumah and Badrie (2005) used to define the cutoff between high and low consumption.

4.2. Fruit Sourcing

The largest effect on frequency of consumption was seen from those who grow their own breadfruit, which potentially increased consumption fourfold. Furthermore, because the largest number of respondents (58.4%) indicated that they source their breadfruit from a friend or family member’s backyard tree, owning a tree not only suggests greater consumption for the grower but likely indicates increased consumption for their friends and relatives. These results are interesting in light of tree giveaways by state or community organizations. For instance, the Plant a Tree of Life (PATOL) project initiated by the Breadfruit Institute at the National Tropical Botanical Garden in October of 2012 worked with over 200 organizations throughout the state to distribute 10,480 breadfruit trees[13]. A recent study indicated that 67% of the trees are growing optimally in backyard locations[13]. Combining these results with our survey indicates that the PATOL program may result in 154,000 more servings of breadfruit being eaten in Hawai’i each year by the tree owners, with additional impacts on their friends and family. This would equate to 136,675 kg of fresh fruit production. Interestingly, this is on the order of the total current commercial sales of breadfruit in the state, demonstrating the importance and impact of such projects (N.K. Lincoln, pers. comm). Consumer surveys can play a role in providing meaningful metrics of the impacts of such programs.

The number of sources where participants accessed breadfruit was positively correlated with increased consumption. This correlation could be driven by either direction: either the more an individual has access to breadfruit the more they consume or, conversely, the more people want to consume breadfruit the more sources they need to identify. We tend to favor the latter explanation. Although we did not prompt or analyze the responses, accessibility was expressed as an issue in comment boxes throughout the survey, with statements such as “I would eat more if I could get it.” Accessibility is also implied by the relative importance of breadfruit sources. For instance, 71% of respondents got their breadfruit from backyard trees (either their own or the tree of a friend/family member), while only 5.9% get their fruit from a store or retail outlet. That breadfruit is not reliably available in store, where more residents access their food, suggests the need for consumers to identify a range of sources in order to consume regularly.

4.3. Consumer Knowledge and Education

As previous studies have suggested, consumer knowledge appears to play a role in consumption. Educational strategies to improve consumer awareness of nutrition and cooking methods may be determined with a basic understanding of consumer behavior, which is heavily influenced by individual attitude, self-identification and past associations, among other factors[22,24]. Therefore, education would be most effective if it stimulates positive attitudes toward health and well-being and relates to both traditional and modern-day breadfruit usage and cultivation. In this study, heightened awareness of health benefits correlated with an increase in consumption. Overall, the health benefits that were expressed were rather general and, in some cases, not necessarily a health benefit rather than a statement of what type of food it was. For instance, when asked about specific health benefits, several respondents inputted “source of carbohydrates.” While this is a true statement and breadfruit is high in
carbohydrates, it does not present any indication of why it is (or is not) a good source of carbohydrates. Other respondents demonstrated a more in-depth range of knowledge with responses such as “has a moderate glycemic index” or “is a source of high quality protein.” Overall, we feel that, due to a lack of more probing questions into health benefits, our assessment may have examined perception of health benefits rather than awareness of health benefits. Overall awareness (or perception) is relatively low—less than 50% of people were aware of any health benefits of breadfruit.

In agreement with Roberts-Nkrumah and Badrie (2005), the two most common preparation methods were steaming and baking. In addition, the more preparation methods respondents indicated correlated with them consuming more breadfruit. This could be framed in two ways: those who are consuming more breadfruit are learning more ways of preparing it, or the more ways you know how to prepare it, the more breadfruit you eat. Presently, there are no case studies that reflect positive impact of culinary and health courses for breadfruit specifically; however, studies have been conducted that attest to communal benefits in improved diet by the intervention of educational courses in food preparation and nutrition [25,26]. In either perspective of consumption patterns, education in creative and traditional breadfruit preparation would further encourage consumption.

5. Conclusions

The purpose of this study was to examine consumer behavior, considering variables that may or may not impact breadfruit consumption by Hawai’i residents. Ultimately, breadfruit in Hawai’i appears to be largely accessed and consumed outside of traditional consumption channels, with backyard trees being a primary source of consumed fruits. Such consumption pathways may be responsive to community-based education and interventions such as tree giveaways and culinary workshops. As part of larger efforts to revitalize underutilized traditional crops, increased awareness and mainstream use has many barriers, and while substantial progress has been made, we argue that this work suggests there is still a long way to go to normalizing breadfruit and incorporating it into the food system more broadly [27]. In particular, stores and restaurants play an almost negligible role in the consumption of breadfruit. In this arena, awareness of health benefits, cultural history, and environmental sustainability of the crop could likely be leveraged to generate greater interest among consumers. Future work could be improved by selecting more specific questions, perhaps similar to that of Roberts-Nkrumah and Badrie (2005), for respondents, such as awareness of particular cultivars, or willingness to attend a grower’s workshop or educational breadfruit culinary class. More research can be conducted in the development of labelled nutritional information and serving size to improve accessibility and bring the crop to more local markets and grocery stores.

Author Contributions: Conceptualization, A.N.; Methodology, A.N. and N.L.; Formal Analysis, A.N. and N.L.; Investigation, A.N.; Resources, N.L.; Data Curation, N.L.; Writing—Original Draft Preparation, A.N.; Writing—Review & Editing, N.L.; Visualization, N.L.; Funding Acquisition, N.L.

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Conflicts of Interest: The authors declare no conflict of interest.
Appendix A

Figure A1. Principle component analysis illustrating the relationships between total breadfruit consumption (A), awareness of health benefits (B), total preparation methods applied (C), and total fruit sources (D).

Figure A2. Parallel coordinate plot showing the cluster means of five clusters determined using a K-mean method. Despite variable levels of preparation methods and fruit sources, which tend to move in parallel with each other, awareness of health benefits is consistently associated with higher total fruit consumption.
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