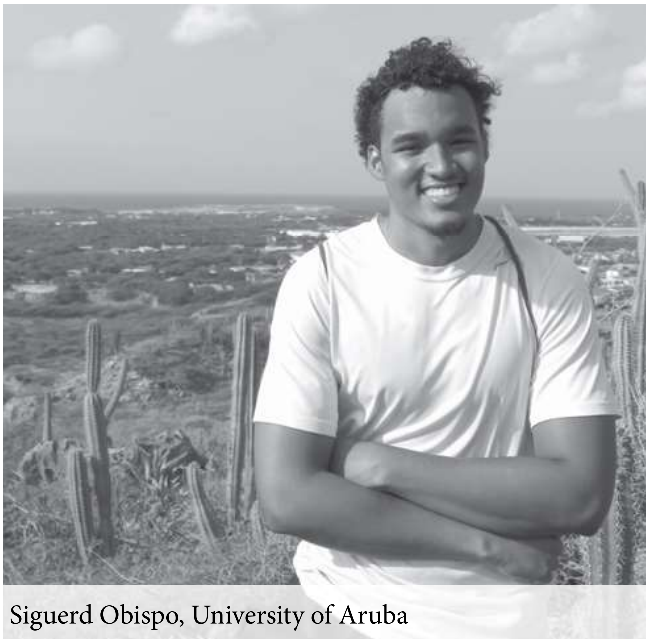
Food drying and food security: the case of the Aruban mango



Siguerd Obispo, University of Aruba

I learned so many new things about my island.

Reflecting on the time spent being part of this project isn't easy to do. This project was interesting and helped me understand a lot about the island I call home, issues I haven't even been aware of, and places I haven't been/explored even though the island isn't visible on the global map because of its small size is an interesting way of finding out how little you know about the place that someone might call home. The program is also a fascinating experience into compromises, learning to work with someone with a different perspective than you, and working together to create something amazing. It's also something that inspires hope for me when it comes to looking at the future, as my outlook on the future before the program was honestly a pessimistic one. Hope is something that one should have for the future which is a great lesson to leave the program with and one I will do my best not to forget.

I would like to express my heartfelt gratitude to everyone in the UCU program I've met and worked with as I learned so many new things about my island and their own countries in such a short time.

Food drying and food security: the case of the Aruban mango

Siguerd Obispo

Introduction

The COVID pandemic negatively affected Aruba's economy due to the island's reliance on tourism (World Bank 2020), resulting in a significant rise in awareness of Aruba's fragile food security. However, The pandemic shed light on Aruba's agriculture industry, with initiatives being made to help Aruban food entrepreneurs through microfinancing initiatives that receive government backing (Rendell de Kort et al 2024). While the Aruban food industry is moving forward it still has its' limitations. One of these limitations lies with a fruit that is cultivated here on the island: the Aruban mango. The Aruban mango grows year-round and is cultivated all around the island. The current issue with Aruban mangoes is that a tree will produce a large amount of ripe mangoes in a short amount of time. This leads to a significant portion of the harvest perishing and not being fully utilized for consumption. A potential solution to this problem for fruits and vegetables is drying them. This will not only extend the shelf life of the mangoes but will also minimize the food waste produced. However, the drying characteristics of the Aruban mango are not well documented. Without this data or knowledge on food drying practices, it would be difficult to make drying of the Aruban mangoes more widespread as we don't have information on the optimal drying conditions. This research paper aims to take the first step in solving this problem by testing the drying characteristics of Aruban mangoes and giving the results to give baseline comparative data for mango drying, which can be used to for testing drying effectiveness of different drying techniques and make fruit and mango drying more widespread on the island of Aruba.

Literature review

When looking at the drying characteristics of mangoes, it is important to look at past experiments on similar produce and how they have been able to gather this data. McMinn and Magee(2003) experimentally describe the adsorption and desorption isotherms for specific types of potatoes, using mathematical models to interpret the data derived from their experiments. They use a standard gravimetric static method to determine the moisture adsorption and desorption isotherms at various temperatures and various humidities. Their methodology emphasizes precision in the gravimetric static approach. The setup involves placing triplicate samples of potatoes in desiccators, and experimental food dryers, in a total of 7 different saturated salt solutions to create constant humidity environments. The reliability of this methodology is further enhanced through their approach to equilibrium content where the samples were kept for 3 weeks until a constant weight was reached (equilibrium). The potatoes' bone dry mass was determined by keeping the samples in the oven at 105-110 C for 8 hours. The significant finding of this study is the type 2 characteristics of the adsorption and desorption isotherms and their' temperature dependence for the total adsorption and desorption capacity. This means that the adsorption and desorption capacity is decreased with increasing temperature. The Guggenheim–Anderson–de Boer (GAB) and Halsey models were found to be able to describe the adsorption and desorption characteristics of these potatoes adequately. It means this model could be key in predicting the adsorption and desorption characteristics of the Aruban mangoes as well. This research and its methodology serve as the basis for getting the desorption and adsorption characteristics of our mango as explained in the following section of this paper.

Methodology

The adsorption and desorption characteristics of the Aruban mango are determined by the standard gravimetric technique with the mango being sliced into thin discs of 1 cm and then placed on simple Petri dishes with 7 saturated salt solutions to properly simulate a constant humidity environment as well as an environment with a different temperatures to put in temperature-controlled cabinets. Preferably this is done at temperatures ranging from 30-60 C as food drying for consumption purposes is usually done at those temperatures(McMinn and Magee 2003). The samples are dried in this manner until they reach a constant equilibrium weight, then using the oven drying method, where we put the samples in the ovens at 105-110C for 8 hours we can measure the bone dry weight of the mangoes. We then start using models to describe the experimental adsorption and desorption data. For this research, there are 2 models which come to mind for modeling the adsorption and desorption characteristics The 2 models used are as follows:

GAB (Van den Berg & Bruin, 1981)

$$X = X_0 C K a_w / [(1 - K a_w) \times (1 - C K a_w + C K a_w)]$$

Halsey (Halsey,1948)

$$X = [\frac{-A}{ln\,(a_w)}]^{1/B}$$

Figure 1: Formulas for the GAB and Halsey Models

MRE%

The models' effectiveness are compared using the MRE % by Chen & Morey:

$$MRE = \frac{100}{N} \sum \left|\frac{M_e - M_p}{M_e}\right|$$

Figure 2: MRE% Formula

Heat Involved in Water Absorption

When water is absorbed by something solid (like when drying mangoes), we measure how much energy this process needs. This is the isosteric heat of sorption which will help us understand how tightly the water is held by the solid. We calculate this energy by comparing it to the energy needed to turn water into steam (vaporization). This is calculated from the experimental data using the Clausius–Clapeyron equation (Figure 3)

$$\left[\frac{d(ln\,a_w)}{d\,(\frac{1}{T})}\right]_X = \frac{\Delta h_d}{R}$$

And

$$\Delta h_d = \Delta H_d - \Delta H_{vap}$$

Figure 3: Clausius Clapeyron application

This value measures how much energy is used when water molecules stick to a solid at a specific level of moisture (X). By drawing a graph that shows the relationship between water activity (aw) and the inverse of temperature (1/T) for a certain moisture level, we can figure out the energy needed for the drying process (Dhd) by looking at the slope of the line (Dhd=R). This method assumes that the energy change (Dh) doesn't vary with temperature and requires us to look at how moisture is absorbed or released at more than two different temperatures.

Enthalpy-entropy compensation theory

The enthalpy-entropy compensation theory explores how the heat required for water absorption (isosteric heat, DHd) and the disorder (differential entropy, DSd) during absorption relate to each other. This relationship can be represented mathematically as:

$$(-ln\ a_w)_X = \frac{\Delta H_d}{RT} - \Delta S_d/R$$

By graphing ln(aw) against 1/T for a specific moisture level (X), we can calculate DHd from the graph's slope and DSd from where the line crosses the y-axis. This method lets us see how DHd and DSd change with different moisture levels.

According to the theory, there's a direct line relationship between DHd and DSd:

$$\Delta H_d = T_\beta \Delta S_d + \alpha$$

We use linear regression to find the isokinetic temperature (Tb) and a constant (a). To test this theory, we compare Tb to the harmonic mean temperature (Thm); the theory holds true if Tb does not equal Thm.

This theory also helps us understand how temperature influences water absorption. By modifying the equation to:

$$T_{hm} = \frac{n}{\sum\ (\frac{1}{T})}$$

we ignore parameter a because it doesn't significantly impact the enthalpy change.

To further examine temperature's effects on absorption, we adjust the equation to:

$$(a_w) = \frac{\Delta H_d}{R(\frac{1}{T} - 1/T_\beta)}$$

where WT is a temperature adjustment factor in the isotherm equation, calculated as:

$$\Psi_T ln\ (a_w) = K\ \Phi(X)$$

and U(X) is a formula that depends on moisture, reflecting the link between water activity and moisture content. This adjustment ensures that data at different temperatures align when graphed according to this equation. Following this approach, we find that an exponential function can describe this relationship:

$$\Psi_T ln\ (a_w) = K_1 K_2^m$$

For the overall heat and disorder from water absorption at a constant condition (net integral enthalpy, Dhin), it's calculated similarly to isosteric heat but under a constant pressure. Graphing ln(aw) against 1/T under this pressure lets us find Dhin from the slope. We calculate the spreading pressure (p) and adjust the values for the relationship between a_w and X at very low aw values (aw = 0.05 used as a practical lower limit). The overall disorder associated with water absorption (integral entropy, DSin), reflecting the system's disorder at different temperatures and pressures, is derived from:

$$\Delta S_{in} = -\left(\frac{\Delta h_{in}}{T}\right) - R\ ln\ (a_w^*)$$

Relevance

This research serves as the first step to understanding the potential of drying local mangoes on a more scientific level, as there is currently no data available on the thermodynamic properties of the Aruban mango, this research can also pave the way for a more developed understanding of of the thermodynamic properties of local foodstuffs. In the case of mangoes, it will aid the local market by starting to understand how to dry the mangoes in the most efficient way possible. This focus on efficiency will lead to less spoilage of the mangoes and contribute to the strengthening of the local food production market. This research will also provide a basis for further comparative studies, particularly in evaluating the efficiency of drying methods as there are different types of dryers, including sustainable ones such as a solar-powered food dryer (Hermans & Vandommele, 2021) and currently being worked on by Kailas Malwade This paper describes using the oven drying method to compare the drying efficiency of their food system to its' bone-dry mass. The research currently conducted in Aruba will allow us to do the same for the Aruban mango, and by extension for other produce, by providing a baseline for comparison by getting a range of bone-dry mass values for these local products.

Future outlook

Potential challenges: Currently, there is difficulty with gathering the equipment necessary for the isothermic analysis of mangoes, so it is important to maximize productivity when the equipment arrives, as well as being able to get Aruban mangoes of a consistent quality will be a notable challenge in this research. Being able to carry over the methodology mentioned earlier will also depend on the equipment and the ability to record data, as data reliability will be a top priority.

Another important factor to consider is the climate the island faces as the experiments will be conducted during the summertime when the climate will be a bit hotter than usual.

Overall, this research is moving along and data collection and experimentation will start sometime soon and an update will be provided when that time arrives.

References

- de Kort, R., Obispo, S., Carmona Baez, A., Echteld, L., & Mijts, E. (in press/2024). Strengthening economic resilience in small island states: A situational analysis of food entrepreneurship, with a focus on the Cucumis Anguria cucumber in Aruba.
- McMinn, W.A.M., & Magee, T.R.A. (2003). Thermodynamic properties of moisture sorption of potato. Food Process Engineering Research Group, School of Chemical Engineering, Queens University Belfast.
- Wolf, M., Speiss, W. E. L., & Jung, G. (1985). Standardization of isotherm measurements. In D. Simatos, & J. L. Multon (Eds.), Properties of water in foods (p. 661). Dordrecht: Martinus Nijhoff.
- World Bank. (2020). Building Aruba's food security during the COVID-19 pandemic and beyond. Global Facility for Disaster Reduction and Recovery. https://www.gfdrr.org/en/publication/building-arubas-food-security-during-covid-19-pandemic-and-beyond