# Sorption characteristics of subtropical fruit – Lucuma powder

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# Sorption characteristics of subtropical fruit – Lucuma powder

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**Abstract.** The current scientific research is focused on the Lucuma powder. We were determined the moisture equilibrium data (adsorption and desorption) at three different temperatures: 10°C, 25°C and 40°C and relative humidity from 0.11 to 0.90, using the static gravimetric method of saturated salt solution. The results showed that the sorption capacity decreased when the temperature increases in the conditions of constant water activity. We were used four different mathematical models – modified Chung–Pfost, modified Oswin, modified Halsey and modified Henderson for description of isotherms of Lucuma powder. According to obtained experimental data, we were recommended the modified Halsey model for description satisfactorily the sorption isotherms of powder.

## 1. Introduction

Recent trends in food production is shown a grow of the plant products, rich in functional components. The aim of the enriching ingredients is to lower the energy value of the product and give it healing, prophylactic and dietary properties [1].

Lucuma known as *Pouteria Lucuma* and *Lucuma Obovata* is a subtropical fruit of the *Sapotaceae* family, most cultivated in Peru, Chile and Ecuador. The exotic fruit has a dark green colour, small and round with a diameter of about 10 cm, the inside of which has a stone and the soft structure is yellow. The fragrance (and even flavors) is exceptionally atypical and easily recognizable. Due to the presence of short chain hydrocarbon alcohols as well as volatile esters, aldehydes that together form the multi-layered odour was discovered/identificated more than 50 flavourings [2]. A major proportion of Lucuma world production (88%) is from Peru's highlands [3]. In the Bulgarian trading network, it is in the form of flour and in the specialized stores for organic and healthy foods is located in the "Superfood" [4]. The term "Superfood" was introduced by manufacturers, nutritionists, and coaches. According to specific personal needs, they offered the use of a similar type of product in individual diets [5]. Nowadays, Lucuma was successfully introduced into ice cream, juice, cakes, biscuits, yogurt, chocolate, baby foods and pies [6, 7].

For last decade, Lucuma impressed the European and world market with its unique nutritional qualities. The exotic Peruvian fruit, often compared to nutritional qualities with the mango, is known as „Gold of the Incas“ [8].

Peruvian fruit is recommended for children consumption because it helps their physical development in adults - to regulate metabolism now it contains fibre, niacin (whose deficiency provokes depression), iron, and a small amount of fat.

Lucuma powder is an excellent substitute for sugar and can help satisfy the desire of sweet foods without affecting the human body (unlike sugar or artificial sweeteners). Despite its sweetness, the Lucuma powder contains only 2 grams of natural fruit sugar per every 11 grams of carbohydrates. This making it a low glycemic index food that can help stabilize your blood sugar levels.

After reference research, we didn`t find information on sorption isotherms (adsorption and desorption) and of Lucuma powder. Thus, the aim of the present study was to determine sorption characteristics of subtropical fruit - Lucuma powder.

## 2. Materials and methods

Commercial Lucuma powder, produced in Peru, purchased in Bulgaria by “Internet café-BG” ltd, packed by “Zoya bg Organic Shop” was used in this study.

The equilibrium moisture content (EMC) of Lucuma powder was investigated at 10ºC, 25ºC and 40ºC and water activities $a_w$= 0.11 ÷ 0.90. The static gravimetric method was used [9]. The powder was dried in a desiccator with $P_2O_5$ at a room temperature for 20 days prior to the beginning of the experiment, for the adsorption process. For determination of the desorption process, the samples were hydrated in a glass jar over distilled water at a room temperature. Samples of 1÷0.02 g were weighed in weighing bottles. Eight saturated salt solutions (LiCl, $CH_3COOK$, $MgCl_2$, $K_2CO_3$, $MgNO_3$, NaBr, NaCl, KCl), hold constant water activity environments, were used in the weighing bottles, which were put in hygrostats [10]. All of the used salts were of reagent grade. At high water activities ($a_w$>0.70) crystalline thymol was placed in the hygrostats to prevent microbial spoilage of the powder. The hygrostats were kept in thermostats at 10ºC, 25ºC and (40-0.2)ºC. Samples were weighed (balance sensitivity = 0.0001g) every three days. Equilibrium was ascertained when three consecutive weight measurements showed a difference less than 0.001g. The moisture content (%) was calculated according to [11].

## 3. Analysis of data

For verification of the description of sorption isotherms, we were used the followed models:

Modified Chung-Pfost $$a_w = exp\left[\frac{-A}{t+B}\exp(-CM)\right] \tag{1}$$

Modified Halsey $$a_w = exp\left[\frac{-\exp(A+Bt)}{M^C}\right] \tag{2}$$

Modified Oswin $$M = (A + Bt)\left(\frac{a_w}{1-a_w}\right)^C \tag{3}$$

Modified Henderson $$1 - a_w = exp[-A(t + B)M^C] \tag{4}$$

where: $M$ is the average moisture content, % d.b.; $a_w$ is the water activity, decimal; $A$, $B$ and $C$ are coefficients; $t$ is the temperature, ºC.

A nonlinear, least squares regression program was used to fit the four models to the experimental data (all replications). The suitability of the equations was evaluated and compared using the mean relative error P (%); the standard error of moisture (SEM) and the randomness of residuals [12]:

$$P = \frac{100}{N}\sum\left|\frac{M_i-\widehat{M}_i}{M_i}\right| \tag{5}$$

$$SEM = \sqrt{\frac{\sum(M_i-\widehat{M}_i)^2}{df}} \tag{6}$$

$$e_i = M_i - \widehat{M}_i \tag{7}$$

where: $M_i$ and $\widehat{M}_i$ are experimentally observed and predicted by the model value of the equilibrium moisture content; $N$ is the number of data points; $A$, $B$ and $C$ are coefficients; $df$ is the number of degree of freedom (number of data points minus number of constants in the model).
The monolayer moisture content is calculated using the Brunauer-Emmett-Teller (BET) equation and the experimental data for water activities up to 0.45, for each temperature [10, 13]:

$$M = \frac{M_e C a_w}{(1-a_w)(1-a_w+Ca_w)} \tag{8}$$

where: $M$ is the monolayer moisture content, % d.b.; $a_w$ is the water activity, decimal; $C$ is the coefficient.

## 4. Results and discussion

The obtained mean values of EMC, based on triplicate measurements for the respective water activity and temperature, are presented in Table 1 for adsorption and in Table 2 for desorption.

The reason for this is maybe the decomposition of sugars after which the powder starts absorbing larger quantities of water. The same effect also applies to the processes of adsorption and desorption. We were funded the similar results, which are reported in the scientific literature, for many foods [14, 15]. The results of the EMC increase with an increase in the temperature at constant $a_w$. The effect on this type of powder is also manifested in other food products high in sugars.

**Table 1.** Equilibrium moisture content M[a] (% d.b.) of Lucuma powder by adsorption at different water activities ($a_w$) and temperatures t (°C).

| **Sel** | **10 ºC** | | | **25 ºC** | | | **40 ºC** | | |
|---|---|---|---|---|---|---|---|---|---|
| | $a_w$ | **M*** | **sd**** | $a_w$ | **M**** | **sd**** | $a_w$ | **M**** | **sd**** |
| **LiCl** | **0.113** | 3.88 | 0.01 | **0.113** | 2.99 | 0.05 | **0.112** | 2.33 | 0.04 |
| **$CH_3COOK$** | **0.234** | 4.60 | 0.14 | **0.225** | 3.96 | 0.20 | **0.201** | 3.26 | 0.17 |
| **$MgCl_2$** | **0.335** | 4.76 | 0.08 | **0.328** | 4.49 | 0.05 | **0.316** | 4.03 | 0.05 |
| **$K_2CO_3$** | **0.431** | 8.16 | 0.19 | **0.432** | 5.72 | 0.01 | **0.432** | 5.13 | 0.05 |
| **$MgNO_3$** | **0.574** | 9.27 | 0.15 | **0.529** | 7.40 | 0.16 | **0.484** | 7.01 | 0.14 |
| **NaBr** | **0.622** | 9.45 | 0.06 | **0.576** | 8.17 | 0.02 | **0.532** | 7.54 | 0.20 |
| **NaCl** | **0.757** | 23.21 | 0.08 | **0.753** | 14.10 | 0.10 | **0.747** | 13.97 | 0.40 |
| **KCl** | **0.868** | 39.79 | 0.20 | **0.843** | 20.77 | 0.16 | **0.823** | 19.57 | 0.30 |

**Table 2.** Equilibrium moisture content M[a] (% d.b.) of Lucuma powder by desorption at different water activities ($a_w$) and temperatures t (°C).

| **Sel** | **10 ºC** | | | **25 ºC** | | | **40 ºC** | | |
|---|---|---|---|---|---|---|---|---|---|
| | $a_w$ | **M*** | **sd**** | $a_w$ | **M*** | **sd**** | $a_w$ | **M*** | **sd**** |
| **LiCl** | **0.113** | 4.41 | 0.04 | **0.113** | 2.75 | 0.08 | **0.112** | 2.13 | 0.08 |
| **$CH_3COOK$** | **0.234** | 5.16 | 0.17 | **0.225** | 3.83 | 0.25 | **0.201** | 3.59 | 0.08 |
| **$MgCl_2$** | **0.335** | 5.92 | 0.05 | **0.328** | 4.40 | 0.24 | **0.316** | 3.76 | 0.06 |
| **$K_2CO_3$** | **0.431** | 8.47 | 0.20 | **0.432** | 4.83 | 0.17 | **0.432** | 4.68 | 0.26 |
| **$MgNO_3$** | **0.574** | 9.25 | 0.15 | **0.529** | 6.91 | 0.21 | **0.484** | 6.29 | 0.13 |
| **NaBr** | **0.622** | 10.99 | 0.21 | **0.576** | 7.66 | 0.04 | **0.532** | 6.89 | 0.14 |
| **NaCl** | **0.757** | 22.10 | 0.23 | **0.753** | 13.02 | 0.18 | **0.747** | 12.79 | 0.11 |
| **KCl** | **0.868** | 38.12 | 0.06 | **0.843** | 17.90 | 0.04 | **0.823** | 16.50 | 0.07 |

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Figure 1 gives the experimental data obtained after adsorption and desorption at 10°C. The sorption isotherms have an *S*-shape profile. The hysteresis effect is statistically significant, at a level of significance α=0.05, in the water activity range 0.4÷0.85.

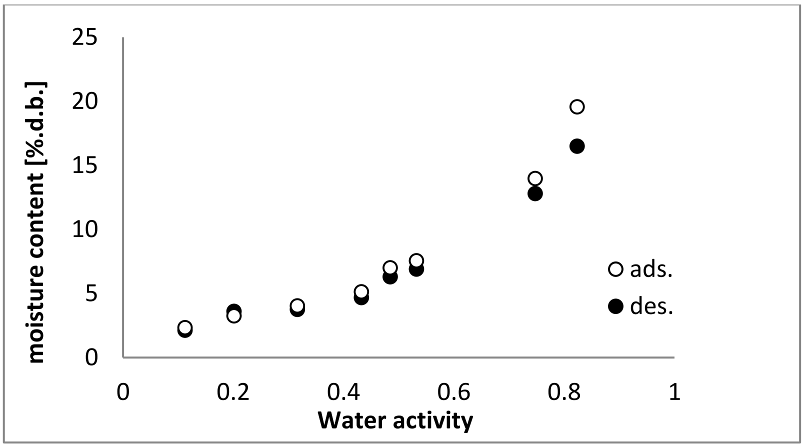


**Figure 1.** Comparison of isotherms at 10°C, Desorption and Adsorption.

The coefficients for the three-parameter modified models, P and SEM values are presented in Table 3 for adsorption and Table 4 for desorption.

**Table 3.** Model coefficients (*A*, *B*, *C*), mean relative error (P, %), standard error of moisture (SEM) and Correlation coefficient (R) for adsorption.

| Model | *A* | *B* | *C* | *P* | *SEM* | *R* |
|---|---|---|---|---|---|---|
| Oswin | 9.88225 | 0.10658 | 0.75756 | 23.77 | 2.18 | 0.97 |
| **Halsey** | **2.20304** | **0.00940** | **1.17891** | **10.03** | **1.29** | **0.99** |
| Henderson | 0.000688 | 78.3072 | 1.09329 | 21.59 | 3.08 | 0.96 |
| Chung-Pfost | 408.4274 | 0.16189 | 135.584 | 24.12 | 4.69 | 0.95 |

**Table 4.** Model coefficients (*A*, *B*, *C*), mean relative error (P, %), standard error of moisture (SEM) and Correlation coefficient (R) for desorption.

| Model | *A* | *B* | *C* | *P* | *SEM* | *R* |
|---|---|---|---|---|---|---|
| Oswin | 10.52716 | 0.13661 | 0.70741 | 23.95 | 2.19 | 0.97 |
| **Halsey** | **2.492462** | **0.01674** | **1.24790** | **10.07** | **1.31** | **0.99** |
| Henderson | 0.000989 | 39.6782 | 1.17033 | 20.31 | 2.75 | 0.96 |
| Chung-Pfost | 206.1237 | 0.17545 | 51.2206 | 25.24 | 3.27 | 0.95 |

The results show that the lowest P and SEM values were obtained with the Halsey model. The graphical analysis of the residues demonstrates that the distribution is random for both models, which means that both models are suitable for the description of Lucuma poweder sorption isotherms (Fig. 2 and 3). We recommend the Halsey model, because of its lower values of the coefficients.

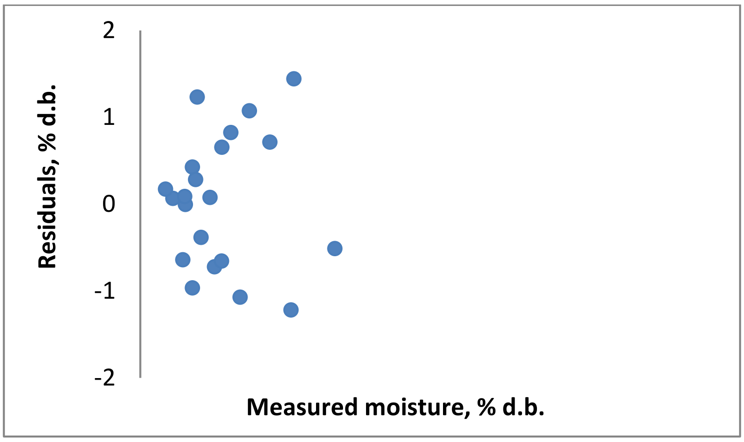


**Figure 2.** Plot of residuals fit of modified Halsey model to adsorption data.

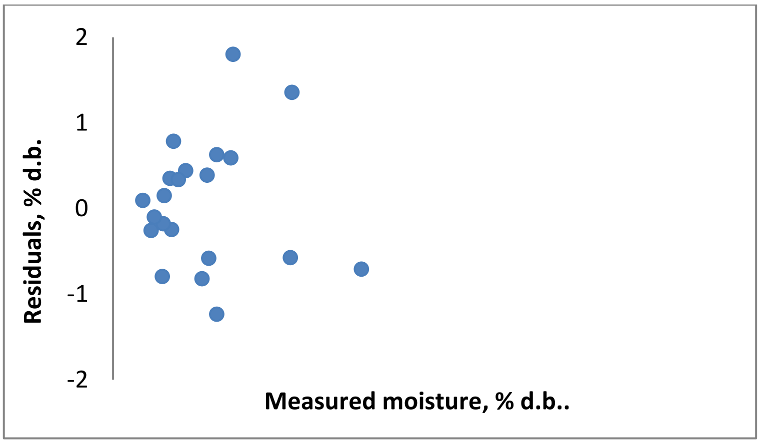


**Figure 3.** Plot of residuals fit of modified Halsey model to desorption data.

The model (8) is linearly transformed for calculation of the BET monolayer moisture content [16]:

$$\frac{a_w}{(1-a_w)M} = P + Qa_w \tag{9}$$

Based on the coefficients of the linear equation, the monolayer moisture content for the respective temperature is calculated and the results are presented in Table 5.

**Table 5.** BET monolayer moisture content monolayer moisture content (% d.b.) of Lucuma powder at several temperatures.

| *t* (ºC) | Adsorption | Desorption |
|---|---|---|
| 10 | 4.18 | 4.17 |
| 25 | 2.93 | 2.56 |
| 40 | 3.65 | 3.21 |

## 5. Conclusions

The sorption capacity of Lucuma powder decrease with an increase in temperature at constant water activity. The modified Halsey model is suitable for describing the relationships between the equilibrium moisture content, the water activity and the temperature of the Lucuma powder. According to sorption isotherms obtained for 10°C, 25°C and 40°C, monolayer moisture content is calculated with BET equation.

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