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# Storage studies of subtropical fruit Lucuma in powdered form

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## Abstract

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In the present paper, we examined Lucuma powder. Nowadays, the subtropical fruit has been considerate as a functional food product with health benefits, a source of bioactive compounds (BAC), knows as part of "Superfoods". The current scientific research is focused on the two different experimental types of storage. The Lucuma powder was packed in a co-extruded barrier film with copolymer covering for heat sealing. The first storage was executed for three months at initial humidity of the product – 9.71%, stored at room temperature – 18°C÷25°C and relative air humidity of 45% to 55%. The storage regime was optimized to six months at the same condition (temperature and relative humidity). Flour was dried to humidity – 2.95%, corresponded monolayer moisture content (MMC), and determined using linealization of Brunauer-Emmett-Teller (BET) equation. Those results about MMC for adsorption were in the range of 2.93% to 4.18 % and for desorption – from 2.56% to 4.17%. During the studies of Lucuma powder, analysis of their microbial load, granulometric composition and moisture content were performed. No living cells of pathogenic organisms (*Escherichia coli, Staphylococcus aureus* and *Salmonella* spp.) or apparent molding were detected. The flour particle size has not changed either.

*Keywords:* lucuma; subtropical fruit; bioactive compounds; monolayer moisture; Brunauer-Emmett-Teller model

## Introduction

Lucuma, namely known as "*Pouteria Lucuma*" and "*Lucuma Obovata*", is a subtropical (exotic) fruit of the *Sapotaceae* family, most cultivated in Peru, Chile and Ecuador. The major portion of the world production (88%) is from Peru's highlands (Andean origin) (Aguilar, 2015). In last years, Lucuma impressed the European and world market with its unique nutritional qualities. The exotic Peruvian fruit, often compared in nutritional qualities with the mango, is also known with the name "Inca Gold" (Caballero & Aguilar, 2017). In the Bulgarian trade network, Lucuma is most common in the form of flour. It is situated in the specialized shops for organic and healthy foods, it is located in the sector "Super foods" (Mukta et al., 2017). This is a term introduced by producers, nutritionists and coaches whose produce individual diets, according to the specific needs of the person (Health & Services, 2017).

Nowadays, Lucuma has been successfully introduced in the production of ice cream, juices, cakes, biscuits, yogurt, chocolate, baby food and pies (Dini, 2011; Fuentealba et al., 2016). The exotic fruit is a good source of beta-carotene, a powerful antioxidant with antihyperglycaemic properties (Erazo et al., 1999; Fuentealba et al., 2016). Lucuma is Peru's most popular scent of ice cream, preferred to vanilla and chocolate. Peruvian fruit is recommended for consumption of children because it helps their physical development in adults - to regulate metabolism. Lucuma contains fibre, niacin (whose lack provokes depressions), iron, and a small amount of fat.

Nowadays, the world trend is a substitution of the used chemically derived medicament with natural sources. Lucuma is a good substitute for rational nutrition because the powder is a good source of many useful nutrients. According to Rojo et al. (2010) Lucuma's fruits have a significant pharmaceutical value, high dietary fibre content and a sweet pleasant taste often compared to caramel (Rojo et al., 2010).

The exotic fruit has a high content of phenol and flavonoid components that make it an excellent ingredient for food products (Taiti et al., 2017). Furthermore, its sweet taste is used as a natural food sweetener (Banasiak, 2003; Dini, 2011).

The determination of the storage regime provides information on the conditions under which products retain their nutritional value. Respecting the recommended storage conditions is provided a long safety and stability of the food. Possible spoilage would be due to inappropriate compliance with the recommended regimes, as well as by the unsupervised grouped storage of different types of organic products. Eventually, the main aim of research is to preserve the food product without disturbing its nutritional value and quality (Sharma et al., 2018). There are different methods for prolonged storage of the product as vacuum packing, packaging in aseptic packing environment, packaging in special packages that do not allow access of air and moisture from the environment to the product and vice versa, baking the product before packing, decreasing the initial humidity of the product to humidity corresponded to the pre-calculated MMC (Jung et al., 2018).

A rich composition of biologically active substances and a high antioxidant activity has been established from the review of literary sources on Lucuma powder. The exotic fruit is characterized as a suitable ingredient for use in food products intended for prevention and treatment. We didn`t find information about the storage regime of Lucuma powder. Thus, the aim of the present study was to determine two different storage studies of subtropical Lucuma powder.

## Materials and Methods

### *Materials*

Commercial Lucuma powder, produced in Peru, purchased in Bulgaria by "Internet café-BG" ltd, packed by "Zoya bg Organic Shop", certified by ABG GmbH BG-BIO-16, was used in this study.

In order to perform the storage studies, the product was packaged in a co-extruded barrier film with copolymer covering for heat sealing designed for food industry, produced by Itaplast "ET – Ilko Tyanevita Plast", Assenovgrad, Bulgaria.

### *Methods*

The moisture content (%) was determined according to AOAC, 1990 (AOAC, 1990).

The microbial load of the product was determined during the storage via:

Mesophilic aerobic and facultative anaerobic bacteria, according to Bulgarian State Standard (BSS EN ISO 4833-1, 2013) (Standard);

Yeasts and fungi, according to BSS EN ISO 21527-2:2011 (Standard);

*Escherichia coli*, according to BSS EN ISO 16649-2:2014 (Standard);

*Salmonella* spp., according to BSS EN ISO 6579-1:2017 (Standard);

*Coagulase-positive staphylococci*, BSS EN ISO 6888-1:2005+A1:2005 (Standard).

Flour particle size was determined with „ProMel LP – 200" sieve analysis equipment. Based on preliminary analysis, the set of sieves was determined as well as their size. The sieving of the sample in the apparatus continues for ten minutes if it amounts to 100 g.

The monolayer moisture content (MMC) for each temperature is calculated by using the Brunauer-Emmett-Teller (BET) equation (Brunauer et al., 1938) and the experimental data for water activities up to 0.60 (Arthur et al., 2018; Bell & Labuza, 2000; Lemus , 2011):

$$M = \frac{M_e C a_w}{(1 - a_w)(1 - a_w + C a_w)}, \quad (1)$$

where:

$M$ is the MMC, % d.b.;

$a_w$ is the water activity, decimal;

$C$ is the coefficient.

All tests were run in triplicate. Data presented are mean values and standard deviations

## Results and Discussion

**First storage study**

***Moisture content***

Humidity is a one of the principal factor influencing on the storage process (Yang Tao, 2018). The moisture content influences on regrouping of flour particuls (agglomeration) and on the development of microbiological organisms (Silva et al., 2014). Lucuma powder was stored at initial humidity in the experimental conditions who imitate a warehouses and markets – temperature from 18°C to 25°C and relative air humidity – from 45% to 55% (Table 1).

**Table 1. Moisture content of Lucuma powder during first storage for three-months**

| *First storage study* | | | | |
|---|---|---|---|---|
| Day/Month | 1 day | 1 month | 2 month | 3 month |
| Humidity, % | 9.71 | 9.93 | 10.31 | 11.35 |

During the first storage, we find a change in moisture content results. The humidity of the sample increases with difference from 0.22% to 1.04%. For three months, the moisture content was in the range from 9.71% to 11.35%, which we believe is due to the packaging.

***The microbial load***

During the first storage, the microbiological parameters for *Escherichia coli*, *Salmonella* sp., coagulase-positive staphylococci, total numbers of mesophilic aerobic and facultative anaerobic bacteria, yeasts, fungi, as well as the granulometric composition were monitored. The results of microbiological tests for the whole period of first storage study are presented in Table 2.

The investigated parameters was performed on first day, first month, second month and third month at temperature between 18°C÷25°C and relative air humidity of 45% to 55%. "Total numbers of mesophilic aerobic and facultative anaerobic bacteria" and "Yeasts and molds" remain from whole period of first storage study, which are below the allowable limits. The result of the analysis shows that *Salmonella* sp was not detected and the presence of *Esherichia* coli and coagulase-positive staphylococci is under the allowable limits from the first day to third month. The microbiological analysis demonstrated that the Lucuma flour could be stored in the condition of the current experiment for the period of three months without microbial deterioration, thus being safe for use.

***Flour particle size***

We were analyzed the distribution of particles size for a first storage study in the selected conditions - temperature 18°C÷25°C and relative humidity of 45% to 55%, as well. The results of the granulometric composition for the same period are presented in Table 3.

**Table 3. Granulometric composition of Lucuma powder during three-month storage**

| № | Particles size, | Quantity of break stock, % | | |
|---|---|---|---|---|
| | μm | Day 1 | Month 1 | Month 3 |
| 1. | 670 | 0.4 | 0.6 | 0.1 |
| 2. | 560 | 0.6 | 0.6 | 0.2 |
| 3. | 450 | 1.2 | 1.2 | 0.5 |
| 4. | 355 | 12.5 | 12.6 | 8.4 |
| 5. | 280 | 0.7 | 0.9 | 0.6 |
| 6. | 200 | 1.9 | 1.2 | 9.3 |
| 7. | 180 | 2.2 | 2.1 | 3.2 |
| 8. | 150 | 4.3 | 4.0 | 31.5 |
| 9. | 132 | 2.4 | 2.3 | 14.9 |
| 10. | 0 | 73.9 | 74.6 | 31.3 |

We found a change in distribution of particle size. Greatest is the amount of flour particles sized less than 132 μm-starting at 73.9% on day 1 and reaching 74.6% after first month and 31.3% on third month. Percentage distribution of the quantity of break stock is similar for particles size over 280 μm for whole period of first storage study. We believe that the finest fractions agglomerate from first to third month due to increasing of humidity in the same period of storage.

**Table 2. Microbiological parameters of Lucuma powder for three-month storage at 18°C÷25°C and relative air humidity of 45% to 55%**

| Sample/ Day | Total numbers of mesophilic aerobic and facultative anaerobic bacteria, CFU/g | *Escherichia coli*, CFU/g | *Staphylococcus aureus*, CFU/g | *Salmonella* sp. / 25 g | Yeasts, CFU/g | Fungi, CFU/g |
|---|---|---|---|---|---|---|
| Day 1 | $9.0x10^4$ | <10 | <100 | Not detected | <10 | <10 |
| Month 1 | $2.0x10^4$ | <10 | <100 | Not detected | <10 | 30 |
| Month 2 | $1.8x10^5$ | <10 | <100 | Not detected | <10 | $1.0x10^2$ |
| Month 3 | $4.0x10^4$ | <10 | <100 | Not detected | <10 | 40 |

However, the change in granulometric composition may be due to selected plastic bags and his permeability. During the first storage study of Lucuma powder, we defined that the size of flour particles is suitable for incorporation into food products.

**Second storage study**

For the second storage study, humidity of Lucuma powder was reduced to an initial humidity corresponded to the calculated monolayer moisture. The purpose of conducting the second experimental storage is to increase the shelf-life of the tested product. In Figure 1 and Figure 2, it was presented the linearization of BET models, namely for the process adsorption and the process desorption for $a_w \leq 0.6$.

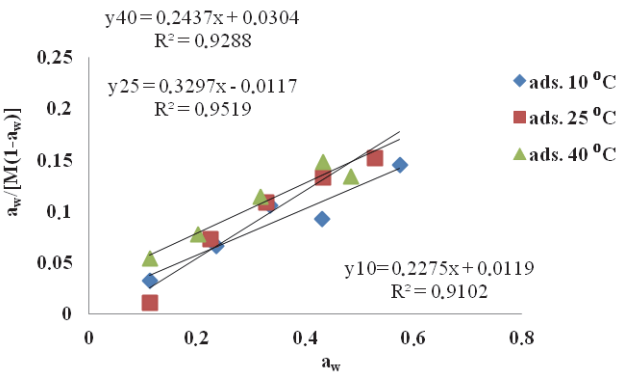


**Fig. 1. Linealization of the BET model, for three temperatures for the process adsorption**

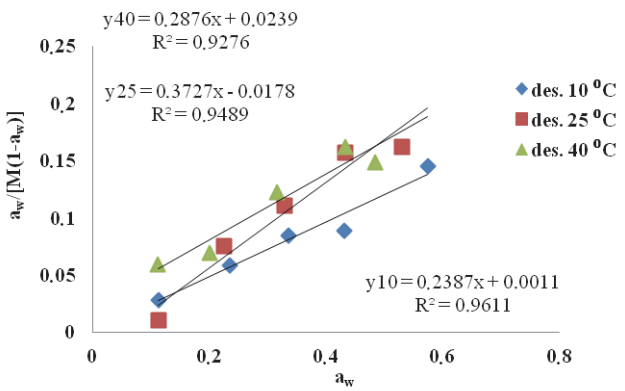


**Fig. 2. Linealization of the BET model, for three temperatures for the process desorption**

MMC for the respective temperature is calculated, based on the coefficients of linear equations (Table 4)

To calculate the BET monolayer moisture content (MMC), the model (1) was linearly transformed:

$$\frac{a_w}{(1-a_w)M} = P + Qa_w, \quad (2)$$

**Table 4. BET monolayer moisture content MMC (% d.b.) of Lucuma powder at several temperatures**

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

As a result of the linearization of the BET model, the maximum values of MMC were at 10°C, followed by 40°C and the lowest values were at 25°C. The results were showed that the temperature did not affect on the MMC for Lucuma powder, which are expressed in both processes of the sorption.

***Moisture content***

Lucuma powder was dehydrated in desiccators with $P_2O_5$ to initial humidity (2.95%) corresponded a recalculated MMC. The sample was stored in the experimental conditions who imitate a warehouses and markets – temperature from 18°C to 25°C и relative humidity – from 45% to 55%. The results are presented in Table 5.

During the second storage, the moisture content was in the range from 2.95 % to 10.00%, which we believe is due to the packaging. We find a change in moisture content results.

***The microbial load***

During the second storage, it was investigated the microbiological parameters for *Escherichia coli*, *Salmonella* sp., coagulase-positive staphylococci, total numbers of mesophilic aerobic and facultative anaerobic bacteria, yeasts, fungi. In table 6 are presented the monitored results for the whole period of second storage study (Table 6).

The result of the analysis shows that *Salmonella* sp was not detected and the presence of *Esherichia* coli, coagulase-positive staphylococci, total numbers of mesophilic aerobic and facultative anaerobic bacteria, yeasts and molds are under the allowable limits from the first day to sixth month of the experimental storage. The investigated microbiological parameters demonstrate that Lucuma flour could be stored in the condition of the current experiment for the period of six months without microbial deterioration, thus being safe for use.

***Flour particle size***

The particle size distribution of Lucuma powder during second storage for six-month is presented in Table 7, as well.

**Table 5. Moisture content of Lucuma powder during second storage for six-months**

| Storage study 2 | | | | | | | |
|---|---|---|---|---|---|---|---|
| Day/Month | 1 day | 1 month | 2 month | 3 month | 4 month | 5 month | 6 month |
| Humidity, % | 2.95 | 6.65 | 7.50 | 8.46 | 8.17 | 8.22 | 10.00 |

**Table 6. Microbiological parameters of Lucuma powder for six-month storage at 18°C÷25°C and relative air humidity of 45% to 55%.**

| Sample/ Day | Total numbers of mesophilic aerobic and facultative anaerobic bacteria, CFU/g | *Escherichia coli*, CFU/g | *Staphylococcus aureus*, CFU/g | *Salmonella* sp. / 25 g | Yeasts, CFU/g | Fungi, CFU/g |
|---|---|---|---|---|---|---|
| Day 1 | $1.5x10^5$ | <10 | <100 | Not detected | <10 | <10 |
| Month 1 | $1.0x10^5$ | <10 | <100 | Not detected | <10 | 50 |
| Month 2 | $1.5x10^5$ | <10 | <100 | Not detected | <10 | $1.0x10^2$ |
| Month 3 | $8.3x10^4$ | <10 | <100 | Not detected | <10 | <10 |
| Month 4 | $8.0x10^4$ | <10 | <100 | Not detected | <10 | 20 |
| Month 5 | $2.0x10^5$ | <10 | <100 | Not detected | <10 | $2.0x10^2$ |
| Month 6 | $1.5x10^5$ | <10 | <100 | Not detected | <10 | $1.0x10^2$ |

**Table 7. Granulometric composition of Lucuma powder during second storage for six-month**

| № | Particles size, μm | Quantity of break stock, % | | | |
|---|---|---|---|---|---|
| | | Day 1 | Month 1 | Month 3 | Month 6 |
| 1. | 670 | 0.6 | 0.6 | 0.6 | 0.5 |
| 2. | 560 | 0.8 | 0.7 | 0.8 | 0.6 |
| 3. | 450 | 1.9 | 2.6 | 2.0 | 0.8 |
| 4. | 355 | 20.2 | 19.5 | 23.3 | 21.5 |
| 5. | 280 | 1.5 | 1.6 | 2.4 | 2.1 |
| 6. | 200 | 20.9 | 19.1 | 1.7 | 1.0 |
| 7. | 180 | 10.7 | 13.0 | 1.7 | 1.9 |
| 8. | 150 | 27.8 | 29.0 | 35.6 | 44.1 |
| 9. | 132 | 4.0 | 3.4 | 7.0 | 6.0 |
| 10. | 0 | 11.5 | 10.5 | 24.9 | 21.5 |

Granulometric composition was monitored on first day, first, third and sixth month. The greatest quantity of particles was had in 150 μm (27.8 % ÷ 44.1%). During the second storage, tendency was to increasing finest fractions below 132 μm from 11.5% to 21.5%. Particle size distribution is similar for fractions over 280 μm for whole period of second storage study. According to our results for six months, we were reported no considerable differences in the granulometric composition of Lucuma powder.

## Conclusions

Humidity of Lucuma powder increases for the both type of storage study.

Microbiological parameters – the total numbers of mesophilic aerobic and facultative anaerobic bacteria were below the permitted levels for this type of food for whole period of two type of storage study. No visible growth of fungi was observed, as well as presence of pathogenic microorganisms.

The monolayer moisture content (MMC) of Lucuma powder is calculated with BET equation: $MMC_{ads}$ = 2.93% ÷ 4.18% and $MMC_{des}$ = 2.56% ÷ 4.17%.

The present study proves that the analyzed Lucuma powder were with high purity and can be stored for up to three and six-month in a co-extruded barrier film with copolymer covering for heat-sealing at 18°C÷25°C and relative air humidity of 45% to 55% for the conditions of the present experiment.

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