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New ready-made mixture for biscuits enriched with subtropical fruit powder lucuma

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Abstract. The consumption of healthy food will always be topical since the intake of unhealthy food has an important impact on a person's energy resources, their state of mind and weight. This served as an impetus for the present study, namely the preparation of a new ready-made mixture for biscuits enriched with bioactive Lucuma fruit powder. We analysed the antioxidant capacity of the product via four different methods DPPH, ABTS, FRAP and CUPRAC, expressed as mM TE/g powder (2.31±0.53; 9.89±0.29; 8.08±0.51; 24.15±1.13, respectively). The essential objective of this study is to obtain experimental data on adsorption and desorption. We evaluated the sorption isotherms for both processes using the static gravimetric method for the temperatures of 10°C, 25°C and 40°C and relative humidity within the 0.11 - 0.90 range. Our results showed that the sorption capacity decreases with the increase in temperature under the conditions of constant water activity. The obtained isotherms were described with four different mathematical models – modified Chung–Pfost, modified Oswin, modified Halsey and modified Henderson. According to our calculations, the modified Halsey model could be recommended for a satisfactory description of the sorption isotherms of the new biscuit mixture. The monolayer moisture content of each temperature was calculated using the Brunauer-Emmett-Teller (BET) equation for adsorption and desorption.
Keywords: Pouteria Lucuma, sorption isotherms, biscuit.

1. Introduction

The dietary habits of contemporary fast-living and stressed-out people often stimulate the development of chronic degenerative diseases. The consumption of healthy food will always be topical since the intake of unhealthy food has an important impact on a person's energy resources, their state of mind and weight. Foods rich in starchy carbohydrates, i.e. potatoes, bread, rice, bakery, and cereals, are a significant source of energy. Foods high in biologically active substances, referred to as antioxidants, protect against the development of malignant tumors and cardiovascular diseases because they strengthen blood cell walls, increase their elasticity, and function as vasodilators [1-2].

Antioxidants stimulate immunity and protect the organism against harmful environmental factors [3]. Dietary fibres affect the human organism in a number of significant ways: they stimulate food digestion by enhancing the secretion of digestive stomach juice; they increase the bulk of food and they give a feeling of satiety after food consumption; they decrease bad cholesterol levels in blood and maintain the necessary good cholesterol range; they help in the elimination of toxins, *etc.* The species cereals belong to, additives, and the technology used in the production of dough products determine the nutritive value of baked goods [4-5].

Lucuma "*Pouteria Lucuma*" is a subtropical fruit belonging to the Sapotaceae family which is mainly grown in Peru, Chile and Ecuador. It is a source of beta carotene, a powerful antioxidant with antihyperglycemic effects [6]. Being rich in many beneficial nutrients, lucuma is a useful supplementary food in healthy diets. According to Rojo et al. [7], lucuma fruit has an important medicinal value, a high amount of dietary fibre and a pleasant sweet taste. Dietary fibre stimulates the elimination of accumulated waste from the large intestine and it also helps the organism metabolize sugar, thereby diminishing the risk of developing type II diabetes. The sweet taste of lucuma makes it possible to use the plant as a natural sweetener [8]. Lucuma powder is an excellent sugar supplement which can satisfy a person's appetite for sugary foods without harming the human organism. Despite its sweetness, lucuma powder contains only 2g of natural fruit sugar for every 11g of carbohydrates. Lucuma has a low glycemic index and can stabilize blood sugar levels [9].

Spelt is a cereal known for 8,000 years since Antiquity. Nowadays it is considered to be a healthier alternative to wheat. Spelt flour is incorporated into various baked goods because it is high in healthy carbohydrate, dietary fibre, plant protein. It also contains important compounds and elements, such as iron, copper, manganese, magnesium, phosphorus, potassium, zinc, selenium, niacin, thiamine, vitamin B6, folic acid. Regular sugars are harmful to diabetics but spelt carbohydrates are beneficial since they are slow to decompose and they do not cause peaks in blood sugar levels [10-11].

The thorough literature review did not provide data concerning any research on spelt-lucuma flour mixes used in the production of biscuits for type II diabetics. This served as an impetus for the present study, namely the preparation of a ready-made spelt-lucuma flour mix and the analysis of its antioxidant activity, physico-chemical parameters, dietary fibre, and sorption characteristics in order to produce biscuits for type II diabetics.

2. Materials and methods

2.1. Raw Material

The study used commercial Lucuma powder produced in Peru, purchased in Bulgaria by "Internet café-BG" Ltd, packaged by "Zoya bg Organic Shop". In order to prepare the new ready-made mixture for biscuits, we used spelt and carob flour designed for the food industry, also delivered by "Internet café-BG" Ltd and packaged by "Zoya bg Organic Shop".

2.2. Method

2.2.1. Physicochemical parameters

The physicochemical composition of the mixture (including the content of moisture, ash, protein, carbohydrates and fat, expressed in %) was determined according to the AOAC, 2007 [12]. The total dietary fibers, insoluble dietary fibers and soluble dietary fibers were determined using K-TDFR-100A (Megazyme, Ireland) according to the AOAC method 991.43 "Total, soluble and insoluble dietary fibers in foods" (First action 1991) and the AACC method 32-07.01 "Determination of soluble, insoluble and total dietary fibers in foods and food products" (Final approval 10-1691) [12].

2.2.2. Antioxidant activity

The ready-made mixture sample was extracted using 10ml 70% ethanol in order to determine the antioxidant activity. Four different methods based on different mechanisms and reaction conditions - DPPH (2,2-diphenyl-1picrylhydrazyl), ABTS (2,2'-azobis (3) -ethylbenzothiazoline-6), FRAP (ferric reducing antioxidant power) and CUPRAC (cupric reducing antioxidant capacity) - confirm the existence of the bioactive compounds in the sample. The procedure is described in detail in an article by Durakova et al. [2].

2.2.3. Sorption characteristics

Procedure. The static gravimetric method was used to determine the equilibrium moisture content (EMC) of the sample at 10ºC, 25ºC and 40ºC and $a_w = 0.11 \div 0.90$ [13]. The ready-made mixture was put in a desiccator with P_2O_5 at a room temperature (from 18 °C to 24 °C) for 20 days before the experiment began (for adsorption). To investigate the process of desorption, the powder was humidified in a glass jar over distilled water at a room temperature. In all weighing bottles, 1 ÷ 0.02 g of the sample was measured. Eight saturated salt solutions (LiCl, CH_3COOK, $MgCl_2$, K_2CO_3, $MgNO_3$, NaBr, NaCl, KCl) assured constant water activity environments. The weighing bottles were placed in hygrostats [14]. These hygrostats were stored in thermostats at 10ºC, 25ºC and 40ºC ÷ 0.2ºC. The moisture content (%) was calculated according to AOAC 960.39 [12].

Data analysis. On the basis of the literature review, the following models were selected to verify the description of the obtained sorption isotherms:

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

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

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

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

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 non-linear 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 [15]. The method followed the description of the procedure in Durakova et al. [16]:

The average relative error $$P = \frac{100}{N}\sum\left|\frac{M_i-\hat{M}_i}{M_i}\right| \quad (5)$$

The standard error of moisture $$SEM = \sqrt{\frac{\sum(M_i-\hat{M}_i)^2}{df}} \quad (6)$$

The distribution of residuals $$e_i = M_i - \hat{M}_i \quad (7)$$
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;
df is the number of degree of freedom (number of data points minus number of parameters in the model).

Brunauer et al. [14], Bell and Labuza [16], and Durakova et al. [17] determined the monolayer moisture content (MMC) through the Brunauer-Emmett-Teller (BET) equation. The calculations of the experimental data include water activities up to 0.45 for each temperature used:

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

where:
M is the MMC, % d.b.;
a_w is the water activity, decimal;
C is the coefficient.

All tests were conducted in triplicate runs. The data presented are mean values and standard deviations.

However, we did not find any information on the preparation of the ready-made biscuit mixture with Lucuma fruit powder or data on its physicochemical composition, antioxidant activity and sorption characteristics. .

3. Results and discussion

We determined the approximate physicochemical composition of the new ready-made biscuit mixture enriched with Lucuma fruit powder: 12.8% proteins, 10.1% moisture, 2.4% fat, 72.4% carbohydrates and 2.3% ash content. The preparation of the new ready-made mixture was provoked by the limited choice of products designed for sufferers of chronic diseases whose diet should restrict the consumption of sugar products. Moreover, the market itself suggested the choice of biscuits because they contain numerous ingredients, such as sugar, wheat flour, various flavours and colorants. We used Lucuma powder as a good source of colour, flavour, bioactive compounds and sugar supplements [6-8, 16]. The analyses of lucuma reavealed that it is rich in dietary fibres: 32.47-35.72% for the different varieties grown in different climatic conditions [4]. Contemporary trends and modern lifestyles necessitate the additional intake of dietary fibres. Dietary fibers change the nature of the contents of the gastrointestinal tract and they also alter the absorption of other nutrients. The health benefits related to the consumption of higher amounts of dietary fiber include the decreased risk of death and the lower rates of coronary heart diseases, colon cancer, and type II diabetes. The soluble fraction was found to normalize the serum lipid levels and decrease the postprandial glucose response. Soluble fibres (including resistant starch) also function as prebiotics and support the probiotics (bacteria) we have in our large bowel which are essential for digestive health. According to our analyses, the new ready-made mixture contains total dietary fibers (TDF): 20.19% ± 0.96, insoluble dietary fibers (IDF): 17.52% ± 1.04 and soluble dietary fibers (SDF): 2.67% ± 0.75. Such products could be considered a source of fibres having in mind that according to European legislation this is possible if food systems have more than 3g per 100g [18]. The agroindustrial wastes from *Pouteria* sp. processing were also found to be a potent source of antioxidants [9].

Antioxidant activity. We obtained a 25.5 ml liquid extract of 1g ready-made mixture. All data (mean ± standard deviation) concerning antioxidant activity are expressed as mM TE/g ready-made powder and presented in Figure 1.

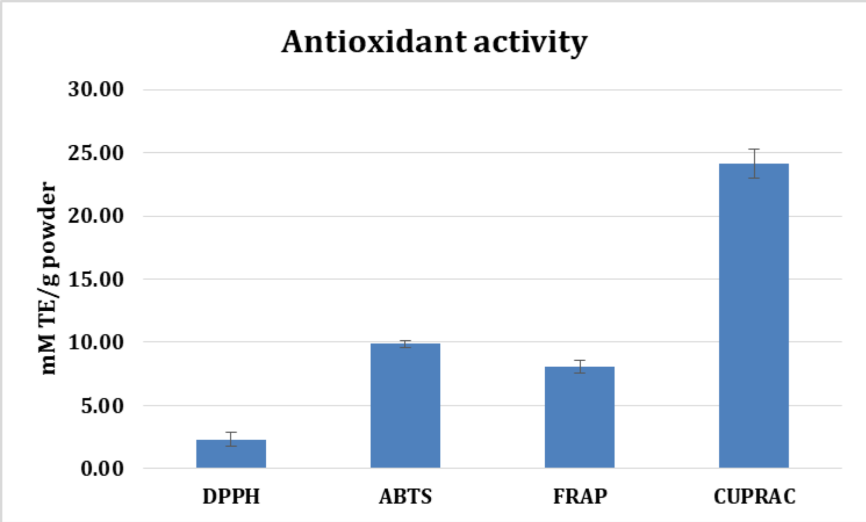

Figure 1. Antioxidant activity of 70% ethanol extract of the ready-made biscuit mixture expressed as mM TE/g powder.

The effect of antioxidant activity is confirmed by the DPPH, ABTS, FRAP and CUPRAC methods used. According to the literature review, there is no information on similar analyses of ready-made mixtures enriched with Lucuma powder. However, there are results about the content of the antioxidants in the methanol extract of *Pouteria Lucuma* seeds confirmed by DPPH (58.14 ± 0.05 µg/ml), ABTS (66.97 ± 0.0 µg/ml) and FRAP (272.50 ± 0.0 µmol Trolox/g dry weight) methods [9]. Yahia and Guttierrez-Orozco [19] and Jun Ma's thesis [20] also report that the Lucuma subtropical fruit possesses antioxidant activity.

Moisture sorption analysis of the ready-made mixture:

Our results concerning the values of EMC are based on triplicate measurements of the respective water activity and temperature presented in Table 1 for adsorption and in Table 2 for desorption.

The obtained results confirm the conclusions of most studies on the sorption isotherms of the food product, such as Muzaffar and Kumar [21] and Decagon [22], that under the condition of constant water activity the EMC increases with the decrease in temperature, as shown in Table 1 and Table 2.

Figure 2 presents the experimental data calculated for adsorption and desorption at 10°C. According to the classification of Brunauer et al. [23], both isotherms obtained are imaged as an *S*-shape profile.

Table 1. Equilibrium moisture content EMC (%) of the ready-made biscuit mixture for adsorption process at different water activities (a_w) and at different temperatures *t* (°C).

	10°C			25°C			40°C		
Sel	a_w	EMC[a]	SD[b]	a_w	EMC[a]	SD[b]	a_w	EMC[a]	SD[b]
LiCl	0.113	5.083	0.11	0.113	4.010	0.08	0.112	2.903	0.16
CH_3COOK	0.234	5.233	0.03	0.225	5.082	0.20	0.201	4.025	0.19
$MgCl_2$	0.335	6.045	0.10	0.328	6.461	0.02	0.316	5.789	0.20
K_2CO_3	0.431	6.120	0.01	0.432	7.160	0.3	0.432	6.246	0.23
$MgNO_3$	0.574	9.403	0.20	0.529	7.938	0.2	0.484	7.263	0.29
NaBr	0.622	10.367	0.21	0.576	9.227	0.21	0.532	7.269	0.19
NaCl	0.757	23.022	0.05	0.753	12.558	0.41	0.747	11.876	0.08
KCl	0.868	31.928	0.23	0.843	16.752	0.08	0.823	15.960	0.11

[a] Mean values based on three replications

[b] Average standard deviation values based on three replications

Table 2. Equilibrium moisture content EMC (%) of the the ready-made biscuit mixture for desorption process at different water activities (a_w) and at different temperatures t (°C).

	10°C			25°C			40°C		
Sel	a_w	**EMC**[a]	**SD**[b]	a_w	**EMC**[a]	**SD**[b]	a_w	**EMC**[a]	**SD**[b]
LiCl	0.113	5.254	0.20	0.113	3.533	0.06	0.112	2.677	0.23
CH_3COOK	0.234	5.671	0.06	0.225	4.560	0.08	0.201	4.170	0.11
$MgCl_2$	0.335	6.886	0.05	0.328	5.494	0.08	0.316	4.949	0.13
K_2CO_3	0.431	7.743	0.04	0.432	5.986	0.12	0.432	5.162	0.17
$MgNO_3$	0.574	9.429	0.3	0.529	6.932	0.04	0.484	5.162	0.05
NaBr	0.622	9.666	0.17	0.576	7.599	0.08	0.532	6.309	0.21
NaCl	0.757	22.637	0.13	0.753	10.976	0.23	0.747	10.842	0.13
KCl	0.868	36.240	0.3	0.843	15.173	0.14	0.823	13.591	0.15

[a] Mean values based on three replications
[b] Average standard deviation values based on three replications

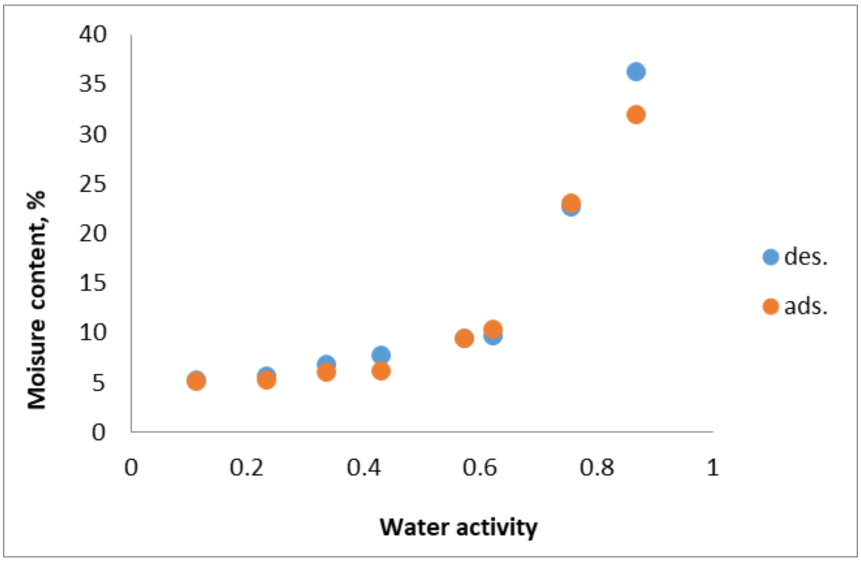

Figure 2. Comparison of isotherms at 10°C, Desorption and Adsorption.

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

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

Models	***A***	***B***	***C***	**P**	**SEM**
Oswin	11.12664	-0.12329	0.57357	21.88	2.22
Halsey	**3.046234**	**-0.00801**	**1.55947**	**10.09**	**2.85**
Henderson	0.000363	67.0626	1.42350	18.10	3.47
Chung-Pfost	314.6677	0.20621	75.1830	24.46	4.81

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

Models	*A*	*B*	*C*	P	SEM
Oswin	11.42943	-0.16943	0.63506	28.01	2.61
Halsey	**3.528500**	**-0.02156**	**1.70475**	**10.08**	**3.90**
Henderson	0.000287	5.81166	2.31119	16.64	6.14
Chung-Pfost	245.5912	0.26108	27.4964	15.61	5.75

The lowest values of P and SEM were obtained with the Halsey model, as shown in both tables (Table 3 and Table 4).

The BET monolayer moisture content (MMC) was calculated by means of the linear transformation of the model (8) (Figure 3 for adsorption and Figure 4 for desorption):

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

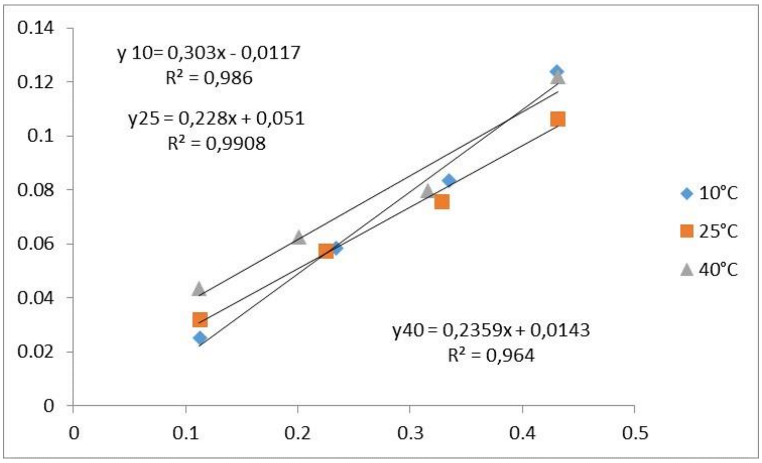

Figure 3. Linearization of the BET model for different temperatures t (°C) for adsorption.

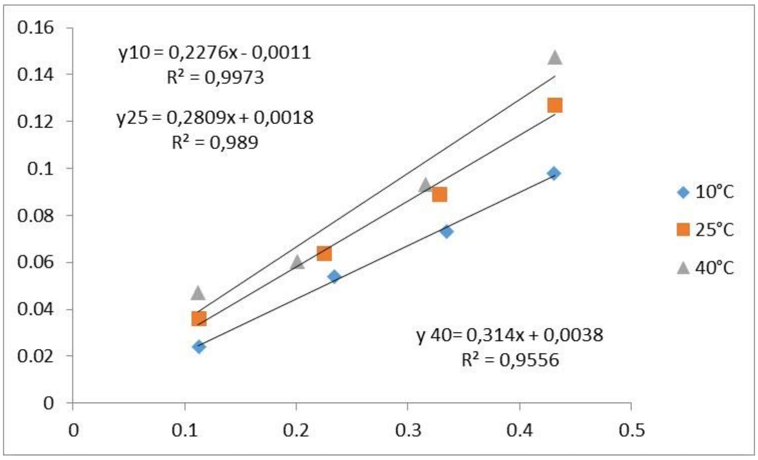

Figure 4. Linearization of the BET model for different temperatures t (°C) for desorption.

On the basis of the linearization of the BET model, the MMC was calculated. The results are presented in Table 5. Table 5 illustrates the obtained values for MMC based on the coefficients of the linear equation for the temperatures of 10°C, 25°C and 40°C.

Table 5. BET monolayer moisture content MMC (% d.b.) of the mixture at several temperatures.

t (°C)	Adsorption	Desorption
10	3.18	4.37
25	3.59	3.54
40	3.99	3.15

4. Conclusions
The approximate composition of the new ready-made mixture was determined. The antioxidant activity was proven via DPPH, ABTS, FRAP and CUPRAC expressed as mM TE/g powder (2.31 ± 0.53; 9.89 ± 0.29; 8.08 ± 0.51; 24.15 ± 1.13, respectively). The sorption capacity of the investigated product decreases with the increase in temperature at constant water. The modified Halsey model is suitable for describing the relation among the equilibrium moisture content, the water activity and the temperature of the new ready-made mixture. With the help of the sorption isotherms obtained for 10°C, 25°C, and 40°C, MMC was calculated with the BET equation (for adsorption – from 3.18% to 3.99% and for desorption – from 3.15% to 4.37%).

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