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Full Length Research Paper

Mass loss, physicochemical characteristics of passion fruit peel (*Passiflora edulis Sims*) submitted to drying process

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The peel of passion fruit has interesting properties, mainly as a source of dietary fiber, but there are few studies concerning the use of this portion of the fruit. This work aimed to evaluate the use of passion fruit peel to obtain flour through the characterization of the physicochemical properties of the peel of fresh passion fruit and subjected to drying process. Subsequently, the samples underwent weight loss process and scanning electron microscopy (SEM). We evaluated the moisture content, dry matter, crude protein and ash, lipids, water activity, instrumental color parameters, absorption rate in milk, the solubility rate in milk, absorption rate in milk drink, rate solubility milk drink, the mathematical modeling of mass loss and scanning electron microscopy to passion fruit peel flour. The quantification of chemical and physical characteristics indicated that the flour may have potential for use in dairy beverages. The considerable concentration of fiber, especially insoluble fiber which obtained value of 23.70%, supposes that this flour can be studied for use in enrichment of food products. Fiber analysis confirmed the presence of this material and SEM showed that the starch can be degraded by drying and lipid extraction. The peel of the passion fruit can be reused by flour production which indicates that fruit has potential for products enrichment.

Key words: Passion fruit, prebiotic, solubility, color, drying.

INTRODUCTION

Passion fruit, popularly known as *maracujá-mirim, maracujá-suspiro, maracujá-peroba, maracujá-pequeno e flor-da-paixão*, whose scientific name is *Passiflora edulis* Sims, of family Passifloraceae, probably originating in Brazil, the world's largest producer, is a tropical plant with broad geographic distribution, which culture is expanding both for the production of fruits for fresh consumption and for juice production (Embrapa, 2011). Passion fruit is grown on small farms, and although it is a high-risk culture due to its high susceptibility to diseases, it has been a very attractive activity for its high added value of production (Meletti, 2011). Alternatives aimed at

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improving co-products from passion fruit processing may result in better economic and financial returns both by processing industries as local processing agribusinesses.

A way of optimizing the use of passion fruit is the development of products from its peel, which is considered waste that is normally intended for animal feed, but lately passion fruit peel has been widely used in food production. The passion fruit peels have been used by some authors. According Otagaki and Matsumoto (1958) peels can be used to supplement animal feed. Ariki (1977) tested such use through the dried peels. In food the yellow passion fruit peel has been tested for the production of common jelly resulting in a product with good texture, taste and acceptable color (Lira Filho, 1995).

Many substances present in passion fruit peel and pulp can provide beneficial effects such as antioxidant and anti-hypertensive activity and reduction of blood glucose level and cholesterol. Despite the great potential of passion fruit as functional food, there are few studies on fruits of species used as food in Brazil (Zeraik et al., 2010). Fiber-based products obtained from passion fruit peel can be formulated to prevent diseases, especially those related to gastrointestinal tract and heart (Córdova et al., 2005). In addition, Stefanello and Rosa (2012) stressed the importance of the full utilization of food for human consumption as an alternative to add nutritional value to preparations, reduce costs and avoid waste.

One of the options of passion fruit peel processing is drying in air circulation systems. Cassava (Vilhalva et al., 2012), soybean (Dal'toé et al., 2012) and pineapple peels (Alexandre et al., 2013) were also submitted to drying process and resulted in products with high technological value capable of being used in food formulations. The drying process aims at removing free water from food in order to concentrate available nutrients, decrease the stored volume and optimize the storage time under ambient conditions, resulting in higher value-added product. In this context, this study aimed to evaluate the use of passion fruit peel to obtain flour through the characterization of the physicochemical properties of fresh peels submitted to drying process.

MATERIALS AND METHODS

Passion fruit obtained from a farm located in the municipality of Santa Helena de Goiás, GO, with altitude of 525 m and 17°37'58"S and 50°33'20" W collected in the months of April to June 2013 were used. Passion fruit seedlings for orchard establishment were characterized as *Passiflora edulis* Sims obtained from juice processing industry, because it is a mixed culture with predominance of yellow and purple cultivars. For study purposes, yellow cultivar was used.

Harvest was performed with passion fruits fallen to the ground or stuck in the plant's branches in the ripening stage where peel was predominantly yellow (Silva et al., 2008), easily loosening from the stalk, and with no injuries or wrinkled peel. Then, passion fruits were sent to the Laboratory of Fruits and Vegetables, Food Engineering Unit of the Federal Institute of Education, Science and Technology of Goiás, Rio Verde Campus, GO, for processing. Passion fruits were sanitized in chlorine solution at concentration of 100 ppm for ten minutes. To obtain flour, passion fruit peels were grinded in Diogomaq® multipurpose grinder previously sanitized with 6 mm matrix. Drying was performed in a drying oven with air circulation and renewal model MA 035 Marconi® at temperature of 60°C and air flow of 7.728 kg / m^2.s.

Three drying processes were carried out with 1 kg passion fruit peel previously grinded. Drying was performed by positioning tray with dimensions of 800 mm × 600 mm in the central area of the drying oven.

The drying curve was obtained by weighing the tray with screened bottom containing the passion fruit peel mass every five minutes in the first hour, 10 in 10 min up to 130 min and then in 20 to 20 min up to obtaining constant weight. After drying, passion fruit shell flour was obtained by grinding mill with polyvalent Diogomaq® 200 mesh and conditioned at room temperature in low density polyethylene bags for later analysis.

To determine the water content ratios of passion fruit peel during drying, the following expression was used:

$$RX = \frac{X - X_e}{X_i - X_e}$$

Where: RX - Moisture ratio, dimensionless; X - Water content at time t, decimal dry basis (kg water kg^{-1} dry weight); X_e - Equilibrium water content, decimal dry basis (kg water kg^{-1} dry weight); and
X_i - Initial water content, decimal dry basis (kg water kg^{-1} dry weight).

Experimental data of passion fruit peel drying were adjusted to mathematical models often used to represent the drying of agricultural products, according to Table 1.

Mathematical models were fitted by nonlinear regression analysis by the Gauss-Newton method, using Statistica 7.0 software. Determinations of components analyzed were performed in triplicate. The models were selected based on the magnitude of the determination coefficient (R^2), mean relative error (P (%)) and root of the mean square error (RMSE). The study considered the value of the average relative error less than 10% as one of the criteria for the selection of models.

$$P = \frac{100}{N} \sum_{i=1}^{N} \frac{\left|Y_{pred} - Y_{exp}\right|}{Y_{exp}}$$

$$RMSE = \left[\frac{1}{N} \sum_{i=1}^{N} (Y_{pred} - Y_{exp})^2\right] {}^\wedge\!\left(\frac{1}{2}\right)$$

Where; Y_{exp} is value experimentally observed; Y_{pred} is value estimated by the model, and N is number of experimental observations.

The proximate composition of the passion fruit peel was performed in triplicate and passion fruit peel flour had nine replicates per analysis: Moisture according to methodology No. 925.09 of AOAC (2000) up to constant weight. Dry matter was calculated as the difference between 100 and the moisture content. Crude protein content was determined according to the micro-Kjeldahl method No. 920.87 of AOAC (2000), using the conversion factor of 5.83. Ash, according to the gravimetric method of AOAC (2000) No. 923.03, with calcination at 550°C and ether extract according to methodology No. 925.38 of AOAC (2000).

In establishing the total, soluble and insoluble fiber, we used the enzymatic-gravimetric method proposed by AOAC (2000), which consisted of sifting the material to then undergo enzymatic digestion with amylase, protease and amyloglucosidase. The enzymes used were provided by Novozymes of Brazil Ltda. The sample digested fibers separated two portions to determine the

Table 1. Mathematical models applied to the drying curves of passion fruit peel.

Model	Model Designation
Lewis	RX = exp(-k*t)
Page	RX = exp(- k*t^n)
Handerson&Pabis	RX = a*exp (- k*t)
Wang & Singh	RX = 1 + a*t + b*t^2
Midilli	RX = a*exp (- k*t^n) + b*t
Aproximação da Difusão	RX = a*exp(-k*t) + (1-a)*exp(-k*b*t)

t, Drying time, min; k, drying constant min^{-1}; a, b, n, model coefficients.

total fiber and the other for the determination of soluble and insoluble fibers. On each fiber, protein determinations were performed and ash, to obtain the corrected values. The samples were analyzed in triplicate, and furthermore, blank tests were also conducted. The percentage contents of soluble, insoluble and total dietary fiber was obtained by the following formula:

$$AF\ (\%) = \frac{RT - P\ C}{m} \times 100\ BT$$

FA = dietary fiber; RT = sample residue mean (mg); P = average residue protein (mg);C = Average of waste ash (mg); m = mass of the sample (mg); BT = RTB - PB CB; RTB = White residue average (mg); PB = average RTB protein (mg), and CB = Ash average RTB (mg)

Water activity (Aw) was determined in apparatus (AqcuaLab, CX-2, Washington, USA) at constant temperature (24 ± 1°C).

The instrumental parameters of passion fruit flour were determined in colorimeter (ColorQuest II, Hunter LabReston, Canada). The results are expressed in L*, a* and b*, where L* values (luminosity or brightness) range from black (0) to white (100), a* chroma from green (-60) to red (60), and b* chroma from blue (-60) to yellow (60), as reported by Paucar-Menacho et al. (2008).

The absorption rate in milk (ARM) was determined by the method of Anderson et al. (1969). About 2.5 g of flour and 30 ml of milk were placed in a previously weighed centrifuge tube. After mixing for 20 s, tubes were kept at 10°C for 10 min and centrifuged at 3000 G in a centrifuge (Sigma, 3-18K, Newport Pagnell, England). The supernatant was removed with the aid of a 10 ml volumetric pipette, only remaining the gel formed in the tube.

The solubility rate in milk (SRM) was also determined by the method of Anderson et al. (1969) with modifications in the drying of the supernatant, where 10 ml of the supernatant obtained from ARM analysis were placed in the weighting bottle and submitted to pre-evaporation in water bath at 90°C and placed in an oven with air circulation for 16 h to determine the evaporation residue and the centrifugation precipitate was weighted. A control was used in triplicate to obtain the amount of milk solids and subtract it from the evaporation residue calculations to determine SRM. ARM and SRM values were determined by Equations (1) and (2) respectively and the results expressed as a percentage and g gel / g dry matter.

$$ARM = Mrg / Ma\ (bs) - (Mre * 3) \quad (1)$$

$$SRM = (Mrg - Mrc) * 3 / Ma\ (bs) \times 100 \quad (2)$$

Mre = evaporation residue mass of sample (g); Mrc = evaporation residue mass of control (g); Ma = sample mass (g), dry basis and Mrg = centrifugation residue mass (g).

The absorption rate in milk drink (ARMD) and solubility rate in milk drink (SRMD) were performed as reported for SRM and ARM, but using fermented milk drink obtained with 60% milk and 40% whey. The mixture was fermented to pH 4.5 using dairy yeast BioRich®

Structural analysis of the passion fruit peel flour was analyzed by scanning electron microscopy (SEM), in which samples were placed on stabs, covered with thin layer of gold and micrographed. Evaluation was performed in High-Resolution Microscopy Multiuser Laboratory at the Institute of Physics, Federal University of Goiás. Scanning Electron Microscope, Jeol, JSM -. 6610, equipped with EDS, Thermoscientific NSS SpectralImaging was used.

RESULTS AND DISCUSSION

Figure 1 shows the passion fruit peel drying curve adjusted by Midilli model (RX = a · exp (- k · t^n) + b · t). When analyzing data, it was observed that there was good agreement between the experimental data and those predicted by the Midilli model. The drying process was homogeneous and constant. The use of global kinetic models is an alternative to predict the drying profiles at different temperatures, making the mathematical models interesting tools to be used during kinetic evaluation of the process within the temperature range established (Durigon, 2012).

Drying occurred up to constant weight of the passion fruit mass. To maintain microbiological safety level of the product, namely to reduce the risk of contaminants, it is desirable to dry the product to moisture ratio lower than 0.15 db (Krokida and Philippopoulos, 2005).

In the drying process of passion fruit peel performed by Ferreira and Pena (2010), the residue at 60°C required longer processing time but provided better color to the product, being the most suitable condition for drying as compared to temperatures of 70 and 80°C. Flour submitted to drying at 60°C represented the best product, as it contains the same total dietary fiber content of other procedures, but showing lower content of cyanogenic compounds (Deus, 2011). In this work, the fiber content was maintained for all drying.

Increasing the drying temperature caused darkening in the product. Darkening is probably due to the exposure of the residue for long time to the drying temperature, favoring the Maillard reaction with the presence of sugars and protein in the residue (Ferreira and Pena, 2010).

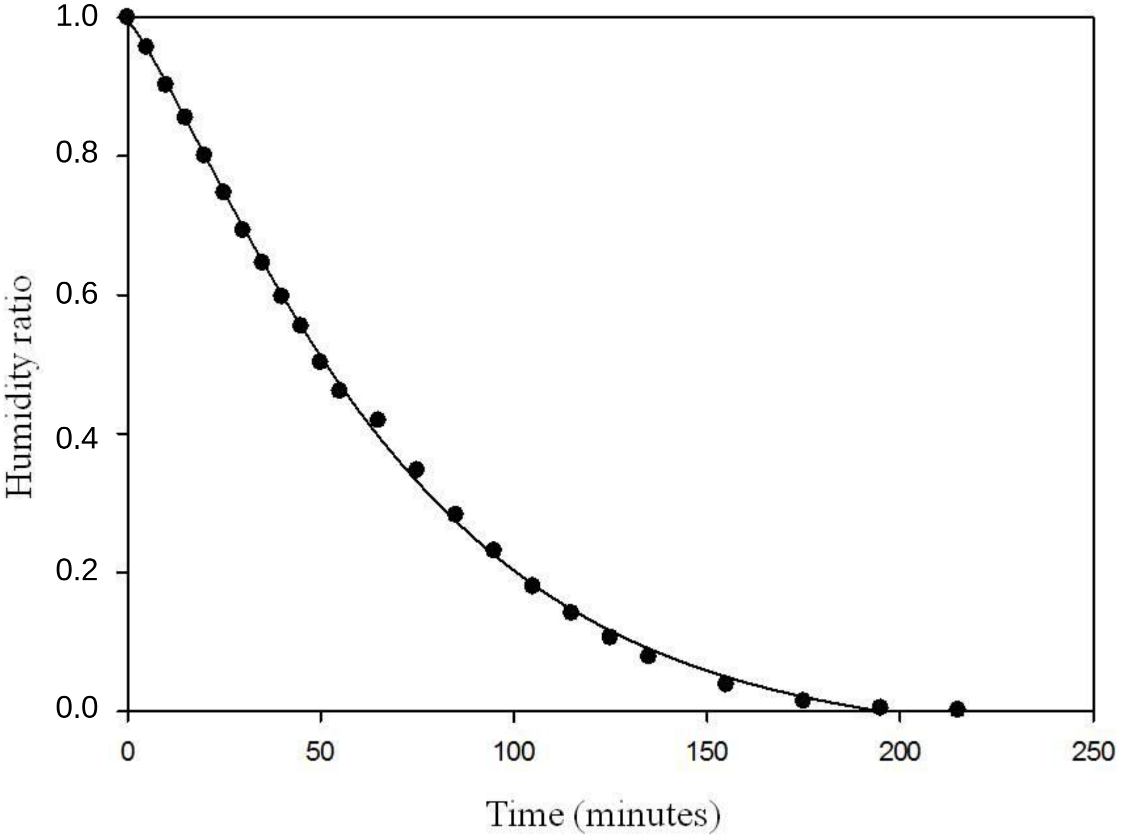

Figure 1. Drying curve of passion fruit peel adjusted by the Midilli model during drying at 60°C.

Table 2. Adjustment parameters of passion fruit peel mass loss for different mathematical models.

Model designation	**60°C**		
	R^2 (%)	**RMSE**	**P (%)**
Lewis	99.14	1.3300	0.1100
Page	99.92	0.2452	0.0144
Henderson & Pabis	99.45	19.6224	0.0463
Wang & Singh	99.93	0.0025	0.0022
Midilli	99.96	0.2043	0.0005
Diffusion approximation	99.91	8.8603	0.0209

Resende et al. (2010) determined the Midilli model as the best adjustment for the drying of adzuki bean with low mean error values, as determined in this work and recommend the Midilli model for drying processes due to its simple mathematical operations and fewer coefficients. Moura et al. (2014) and Spoladore (2014) determined that the Page model was the best adjustment for drying passion fruit pulp (Table 2).

The results of the physicochemical characteristics of passion fruit peel are presented in Table 3.

The average moisture values of passion fruit peel was higher (88.16%) than 87.64% reported by Gondim et al. (2005) and lower than 88.37%, reported by Cordova et al. (2005).

The average dry matter content was 11.84%. The crude protein content of fresh passion fruit peel was 1.84% .With respect to protein and ash levels, Gondim et al. (2005) found 0.67% of protein and 0.57% of ash with results expressed in natural matter. Cordova et al. (2005) reported 1.50% of crude protein and 8.68% of ash on a dry basis.

Table 4 shows the average results of the physic-chemical composition of passion fruit peel flour obtained at constant temperature and air flow conditions. The

Table 3. Mean value and standard deviation of the chemical composition of fresh passion fruit peel.

Parameter	Mean value	Standard deviation
Moisture (%)	88.16	0.12
Dry matter (%)	11.84	0.12
Crude protein (%)	1.84	0.10
Ash (%)	1.23	0.03

Table 4. Physicochemical composition of passion fruit peel flour.

Parameter	Mean value	Standard deviation
Moisture (%)	8.92	0.32
Dry matter (%)	91.08	0.32
Crude protein (%)	15.29	0.53
Ash (%)	8.70	0.42
Ether extract (%)	1.10	0.29
Water activity	0.301	0.0023
L	69.12	2.23
a*	6.31	0.73
b*	20.54	0.81
ARM	6.43	0.34
SRM	11.61	0.41
ARMD	6.46	0.61
SRMD	16.28	0.67
Total dietary fiber	28.28	-
Soluble dietary fiber	5.64	-
Insoluble dietary fiber	23.70	-

ARM, Absorption rate in milk; SRM, solubility rate in milk; AR MD, absorption rate in milk drink; SRMD, solubility rate in milk drink.

results showed that the drying conditions influenced some parameters analyzed in this study. Moisture, dry matter, crude protein, ash and ether extract values of 8.92, 91.08, 15.29, 8.70 and 1.10%, respectively, were found.

The average physicochemical results of passion fruit peel flour of the present study were different from those performed at temperature of 70, 80 and 90ºC, with no significant difference in the results. Souza et al. (2008) obtained 8.66, 1.75 and 12.52% of ash, ether extract and proteins, respectively, in the evaluation of passion fruit peel flour.

For ash contents, the rate the passion fruit peel flour as full under Brazilian law (Brazil, 2005), the ashes are mineral evidence and the higher this value appears darker flour. A considerable amount of potential minerals in the flour provides a higher degree of extraction and the greatest amount of passion fruit peel the bran flour.

The levels of dietary fiber found in this work and by Cordova et al. (2005) indicate that the presence of soluble fiber enables the use of the flour to increase the observed by Ferreira and Pena (2010) for drying temperatures of 60, 70 and 80°C with moisture, protein, fixed mineral residue and ether extract values of 5.9, 6.0, 2.9 and 2.1%, respectively. Likewise, after the drying process, Pena et al. (2008) reported moisture content from 8.7 to 11.0%, protein from 11.3 to 11.6%, ether extract of 1% ash from 3.1 to 3.2% in drying processes consumption of fiber in the human diet. The study by Deus (2011) showed that with increasing temperature there was a significant drop in moisture content (9.62%) and water activity (0.290). Compared with the result of this study, the level of water is considered low, and therefore indicates that the product can be stored for long periods. Although this study did not perform microbiological analyses of passion fruit peel flour during storage for inclusion in fermented dairy drinks, stability was observed, without changes of the physical characteristics during storage for two consecutive years.

Passion fruit peel flour showed coloration with considerable luminosity index. It was observed that the passion fruit peel flour does not have blue, green or red coloration represented by chroma coordinates a* and b*, but the yellow color was the most pronounced for this flour. Ortolan et al. (2010) determined in wheat flour luminosity and chroma b* values greater than those of this work, 97.50 and 7.67, respectively.

The absorption rate in milk and solubility rate in milk indicate that the passion fruit peel flour can be used for the production of milk-based foods. Leoro (2007) showed higher values for absorption rate in milk and solubility rate in milk for passion fruit flour, 12.50 and 14.53, respectively, compared to those obtained in this work. Passion fruit flour is a source of fiber with the presence of pectin that can form complexes and elastic gels, which can justify its low solubility rate in milk (Fagan et al., 2006). Low methoxylation pectin forms gels in the presence of calcium ions; however, the high methoxylation pectin can prevent coagulation of casein at pH below the isoelectric point due to possible chemical reactions (Glicksman, 2000).

These rates are related to absorption and solubility in milk drink, and it was found that the solubility rate in milk drink was higher compared to the solubility rate in milk, which contributes to better appearance and texture of the product when used as alternative for the production of dairy drinks than for the production of milk-based products.

Passion fruit peel is an industrial waste that can be used as an ingredient in the bread industry to enrich the nutritional quality (fibers) of products obtained (Ishimoto et al., 2007). Moreover, there is potential for the use of passion fruit peel flour in the enrichment of products such as bread, biscuits and cereal bars, improving their nutritional and technological quality, being an alternative to reduce the waste of by-products in the food industry (Souza et al., 2008).

The average total dietary fiber value indicates that passion fruit peel can be included in the diet as a source of fiber, according to the Brazilian legislation. According to the technical regulation concerning the supplementary nutrition information (Ordinance nº27), food can be considered a source of dietary fiber when presenting in the finished product, 3 g/100 g (full base) to solid foods (Brazil, 1998). Based on the legislation, the fiber content in the passion fruit peel found indicates, in all aspects, that passion fruit peel contains highly significant values for consumption.

Increased intake of fruits and vegetables as sources of dietary fiber are associated with lower risk of cardiovascular diseases and certain cancers, especially those of the gastrointestinal tract and increased fiber intake is also associated with greater volume of stools and more rapid transit time, thus leading to an improvement of defecation and other gastrointestinal health benefits (Storey and Anderson, 2014).

Defatted passion fruit peel flour has multiform, uneven and fibrous structure. Figure 2 shows particles of different sizes that when present in flours characterize degradation of the molecular matrix of cells. The granular structures can be the result of starch and protein fractions, which are broken by the action of the solvent during the lipid extraction process of passion fruit peel flour (Hess, 1975; Roman-Gutierrez et al., 2002).

The scanning electron microscopy of passion fruit peel flour (Figure 2) shows the presence of starch granules (magnification of 5000x). Fiorda et al. (2013) reported that starch granules have a circular and concave-convex structure and fibrous structures have geometric shapes with gaps and incidence of pores, where there is water absorption.

However, Andrade (2014) reported that although the starch granule has circular and spherical structure in its original form during drying processes, this granule can be changed due to starch gelatinization, losing the original form.

The geometric shapes depicted in Figure 2 may indicate the presence of fiber, which according to previous results of this work are present in the flour passion fruit peel. The scanning electron microscopy indicated the structures present in the flour analyzed by this research. Such structures can be studied in future research to better quantify how they present themselves through chromatography equipment.

Conclusion

The flour of passion fruit peel (*Passiflora edulis* Sims) indicated considerable physical and chemical characteristics for food use due to the low incidence of lipids and proteins rates. The presence of ash are interesting for human consumption, however, may contribute to the oxidation of the product and should be further considered the storage and shelf life of this fruit flour. Drying kinetics showed that Midilli model is the one that best represents this drying process. The analysis of fibers and scanning electron microscopy confirmed that the passion fruit flour has considerable amounts of fiber, but the drying process caused breaks in starch possibly due to gelatinization and degreasing processes.

Conflict of Interests

The authors have not declared any conflict of interests.

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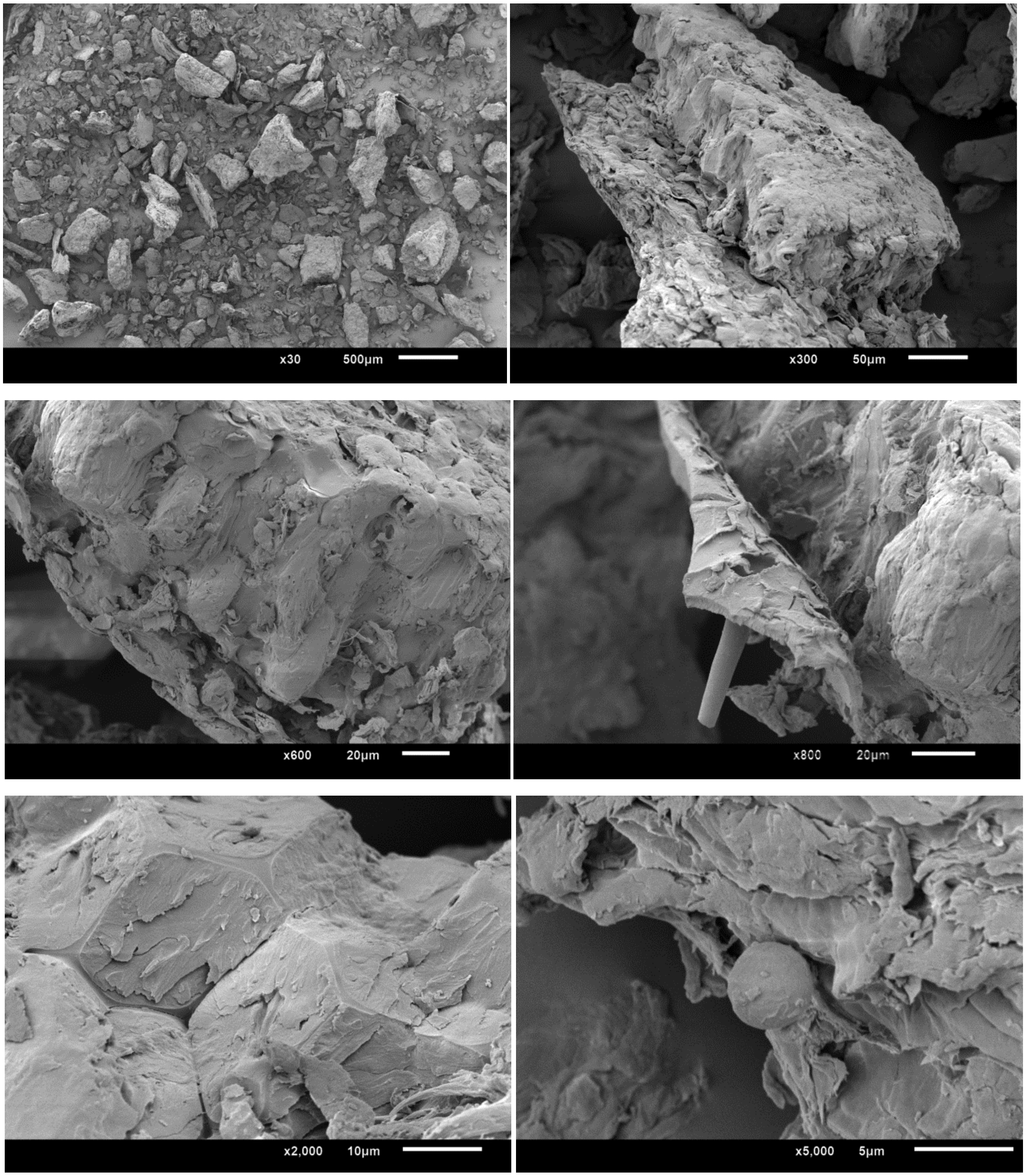

Figure 2. Scanning electron microscopy image of passion fruit peel flour.

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