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Artículos originales

Compresión y caracterización de partículas granulares de *Ipomoea batatas* y *Artocarpus altilis* en tabletas

Compression and Characterization of Granular *Ipomoea batatas* and *Artocarpus altilis* Particles into Tablets

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Conflict of Interest

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Resumen

Introducción: Los comprimidos son formas farmacéuticas sólidas de administración por vía oral, constituidas por un granulado sometido a compresión. Estos, se pueden formar a partir de partículas (excipientes e ingredientes activos) que se deforman bajo presión. Existen una serie de partículas de origen natural provenientes de productos agrícolas que son maleables y se podrían utilizar en como excipientes para la obtención de comprimidos. Sin embargo, existe una brecha de investigación en cuanto al uso de estos productos agrícolas en comprimidos. Este estudio exploró el potencial de utilizar como excipientes granulados químicamente no modificados de *Ipomoea batatas* y *Artocarpus altilis* en la obtención de comprimidos.

Método: La investigación evaluó las propiedades físicas y la solubilidad bajo diferentes condiciones, incluyendo métodos de corte, adición de aglutinantes y fuerzas de compresión. El proceso experimental incluyó secado, molienda, mezcla con aglutinante (Polivinilpirrolidona) y compactación. La caracterización de las partículas incluyó distribución de tamaño, densidad, morfología y porosidad, mientras que el análisis del material compactado se centró en la dureza, friabilidad, tiempo de desintegración y tiempo de solubilidad.

Resultados: Las partículas de *I. batatas* eran esféricas con un D50 de 420 µm y una porosidad del 50%-60%. Las partículas de *A. altilis* eran de forma irregular con un D50 de 120–200 µm y una porosidad del 75%-80%. El material compactado de *I. batatas* tenía una dureza >4 kgf, friabilidad <1%, desintegración de 8-15 min y solubilidad de 14-18 min. *A. altilis* tenía una dureza >4 kgf, friabilidad <2%, desintegración de 2,5-5 min y solubilidad de 5-9 min.

Conclusiones: La adición de aglutinante y las fuerzas de compresión redujeron la pérdida de peso y aumentaron la dureza, el tiempo de desintegración y el tiempo de solubilidad. La composición de carbohidratos (principalmente almidones) afectó significativamente el tiempo de solubilidad, mientras que la técnica de corte influyó en el tiempo de secado, pero no en el comportamiento final del producto. Este estudio demuestra la viabilidad de utilizar materiales granulares obtenidos de productos agrícolas naturales para formar productos comprimidos.

Palabras clave: *Ipomoea batatas*; *Artocarpus altilis*; Caracterización de Tabletas; Excipientes; Comprimidos

Abstract

Introduction: Tablets are solid pharmaceutical dosage forms administered orally, composed of granules subjected to compression. They can be formed from particles (excipients and active ingredients) that deform under pressure. There are several naturally derived particles from agricultural products that are malleable and could potentially be used as excipients in tablet formulation. However, there is a research gap regarding the use of these agricultural products in tablets. This study explored the potential of using chemically unmodified *Ipomoea batatas* and *Artocarpus altilis* granules as excipients in tablet formulation.

Method: The research evaluated physical properties and solubility under varying conditions, including cutting methods, binder addition, and compression forces. The experimental process involved drying, milling, binder mixing (Polyvinylpyrrolidone), and tablet compaction. Particle characterization included size distribution, density, morphology, and porosity, while compacted material analysis focused on hardness, friability, disintegration time, and solubility times.

Results: *I. batatas* particles were spherical with a D50 of 420 µm and 50%-60% porosity. *A. altilis* particles were irregularly shaped with a D50 of 120–200 µm and 75%-80% porosity. Compacted *I. batatas* had hardness >4 kgf, friability <1%, disintegration 8-15 min, and solubility 14-18 min. *A. altilis* had hardness >4 kgf, friability <2%, disintegration 2.5-5 min, and solubility 5-9 min.

Conclusions: Binder addition and compression forces reduced weight loss and increased hardness, disintegration, and solubility times. The carbohydrate (mainly starches) composition significantly affected solubility time, while cutting technique influenced drying time, but not the final product behavior. This study demonstrates the feasibility of using granular materials obtained from natural agricultural products to form compressed products.

Keywords: *Ipomoea batatas*; *Artocarpus altilis*; Tablet Characterization; Excipients; Tablets

Highlight

Current scientific knowledge highlights that *Ipomoea batatas* and *Artocarpus altilis* are potential sources of granular materials for pharmaceutical applications, but their specific compaction and solubility behaviors are less well-understood.

This study shows that unmodified *Ipomoea batatas* and *Artocarpus altilis* can be compacted without extraction or chemical changes, meeting pharmaceutical industry standards for drug formulations.

The findings suggest that using unmodified *Ipomoea batatas* and *Artocarpus altilis* for compaction could lower production costs and offer viable options for drug formulations, supplements, and hypoallergenic products.

Introduction

The blends of different formulations used in compacted oral based drugs (i.e. tablets) often includes a combination of organic and inorganic elements[1]. Organic materials, such as cellulose, lactose, and starch, are widely used due to their benefits including providing a matrix for controlled release of selected ingredients, biocompatibility, renewability, easy availability, and potential nutritional value[2-4]. Among these materials, starch is particularly significant in food and industrial production, commonly used for disintegration, filling, and binding. Starch is typically extracted from food sources using wet milling and drying techniques[5,6]. While both techniques have been widely used, some industrial applications may find the extracted starch unsuitable, leading to the use of alternative methods or requiring chemical modifications to its inherent properties[7].

There is a vast quantity of ongoing studies related to the use of food-derived starch in tablet formulations, particularly as disintegrants or binders. For example, recent studies have focused on using starch as a disintegrant in the formulation development, evaluating the effects of various formulations and pretreatments to the material[8,9].These studies have yielded insights on the improved strength and disintegration made with modified *Ipomoea batatas* starch and the effective application of *Artocarpus altilis* starch as a binder and exo-disintegrant for paracetamol tablets[10,11]. However, studies considering the use of these two agricultural products in their original chemical state for the formation of tablets are scarce or unavailable. This approach has the potential to not only reduce manufacturing steps and costs, but also increase the concentration of nutritional components in the formulation with a material that has been widely used in the food industry.

Recent studies have begun exploring the compaction of chemically unmodified food components. One example is the study where *Manihot esculenta* flours were used to produce tablets at high compression forces and found similar physicochemical characteristics to those obtained with the commercial starch, thus recommending these particles as future disintegrants[12]. Research by Sun, et al.[13] aimed to optimize the formulation of effervescent tablets using mango, Chlorella, and cactus fruit powders as functional ingredients, where their findings indicate that specific ingredient ratios greatly influence the tablet properties, such as disintegration time, tensile strength, and moisture content. Other examples of food-based tablets are using the cactus flour and microalgae biomass for natural supplement tablets[14], preparing fruit powder tablets by direct compaction method using dragon fruit, pineapple, mango, and guava powders[15], developing instant pumpkin soup tablets[16], and using a mixture of guava and dragon fruit powders to create tablets as drinking alternatives[17]. Despite all this, further research is needed to explore and expand the literature on the creation of tablets using a wider variety of food sources.

The goal of this study was to investigate whether chemically unmodified granular material of local *Ipomoea batatas* and *Artocarpus altilis* can be used for the compaction of tablets, and to evaluate its performance using standard characterization techniques. The findings of this research can lay the foundations for the creation of different compacted products, such as tablets, pasta, capsules, energy bars, beauty products, compacted agricultural products, among others.

Materials and methods

Materials

Ipomoea batatas (L), canol cultivar, was provided by the Empresa Agricola Torres Company in Vega Baja, Puerto Rico, while *Artocarpus altilis* (Parkinson) Fosberg, white cultivar, was sourced from the "Plaza del Mercado de Mayagüez" and multiple sectors of Mayagüez, Puerto Rico. Both materials would

classify as natural source excipients (disintegrant purpose only) since both are obtained from food sources.

Polyvinylpyrrolidone (PVP) (Plasdone™ K29/32) from ISP Technology was used as the binder agent to enhance the cohesion and adhesion properties of the tablets and improve their mechanical strength and integrity.

For the reference values, a mixture of Lactose Granulac 140 (Meggle) with Magnesium Stearate (Janssen Ortho) and starch extracted from *Ipomoea batatas* was used. For starch extraction, the tuber was cleaned and peeled, then cut into small pieces for triturating with distilled water, followed by three filtrations with rinses. The filtered suspension was left to settle overnight at 4°C to allow starch sedimentation at the bottom of the container. After decanting the excess water, the sedimented starch was dried in an oven at 55°C for 16 hours and sieved using a 125 µm opening sieve.

Methodology

The process flowchart shown in Figure 1 was followed to produce the tablets either from *I. batatas* or *A. altilis*; from the moment of receiving the material until the final blend compaction. Raw material pre-processing included all the steps required before drying the material, including the cleaning, peeling, and cutting of the raw food. Particle production includes the drying and milling steps of the material for further experiments. This granular material was compacted and characterized during the materials compaction stage.

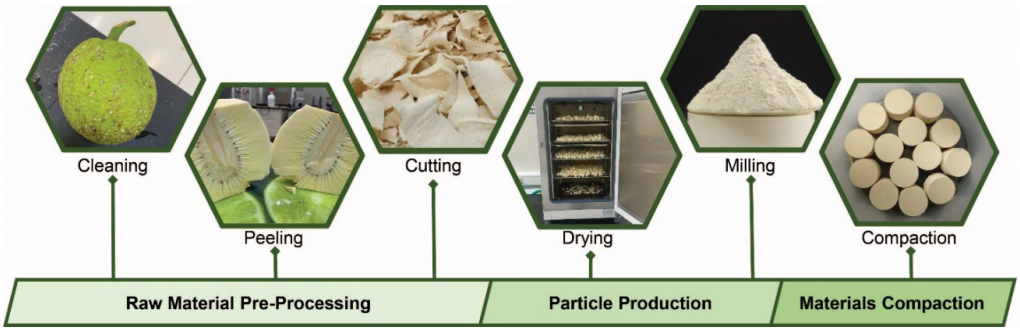

Figure 1. Process flowchart for the tablet compaction of the granular material.

Raw material pre-processing

Upon the arrival of the food, the material was inspected to look for irregularities and cleaned with soap and water to remove outside materials and reduce the microbial load on the surface. The food was then rinsed with distilled water and allowed to fully drain. For peeling the material, an Orangemast Masterfruit Vibrating Peeler was used at medium to high-speed intervals and with blade 7, which has an approximately 6 mm aperture. This equipment was also used for slicing the material with blade 3 of approximately 2.5 mm aperture. The Brunner Anliker GSM5 with a square sieve of approximately 18 mm was used for the cube cut configuration.

Particle Production

Raw cut food samples were dried at 55 °C in a Thermo Fisher Heratherm Oven until the material moisture of the sample was 10 ± 2%. The dried material was milled on a FitzMill Comminutor Model L1A at a 3000 RPM and 685.8 µm round hole perforated screens and then sieved using a sieve diameter of 297 µm and classified into large (≥ 297 µm) and small (< 297 µm) particles. The distribution ratio for *A. altilis* particles was 75% small particles and 25% big particles (similar to its original particle size distribution), while for *I. batatas* was 30% small particles and 70% big particles. For the binder blends, PVP was added at 2% w/w.

To determine the particle size distribution (PSD), samples of 20 to 30 g were analysed using the RTSizer V7.20 software integrated with the Insitec from Malvern Inc. With the histogram plot obtained, we determined de D10, D50, and D90 of the runs and calculated the Span (**Equation 1**) and D90/D10 ratio to have a numerical representation of the uniformity and size consistency of the formulation. Span closer to 0 can be related to samples with a uniform distribution and size consistency while D90/D10 ratios bigger than 5 tend to be indicative of possible segregation.

$$\text{Span} = \frac{\text{D90} - \text{D10}}{\text{D50}} \tag{1}$$

Tapped and bulk density was calculated by the procedures established by the USP <616> Bulk Density and Tapped Density of Powders using a Dual Autotap Tapped Density Analyzer from Quantachrome Instruments. As for particle density, a pycnometer of 25 mL was used with O-xylene from Alfa Aesar based in previous publications with *I. batatas* particles[18]. Particle density was determined using **Equation 2**, where is the pycnometer weight, was the added sample weight, was the pycnometer weight with the sample and the xylene, was the density of xylene, and is the volume of the pycnometer.

$$\text{Particle density} = \frac{W_2 - W_1}{V_{\text{pycnometer}} - \frac{W_3 - W_2}{\rho_{\text{liquid}}}} \tag{2}$$

Knowing these densities, we can calculate the Hausner ratio and Carr's index using **Equation 3** and **Equation 4**, respectively, which can be found in *USP <616> Bulk Density and Tapped Density of Powders* and classify its powder flow behavior using *USP <1174> Powder Flow*. To determine the particle porosity, we can use **Equation 5**, which uses the bulk and particle density.

$$\text{Hausner ratio} = \frac{\text{Tapped density}}{\text{Bulk density}} \tag{3}$$

$$\text{Carr's index (\%)} = \frac{\text{Tapped density} - \text{Bulk density}}{\text{Tapped density}} * 100 \tag{4}$$

A Scanning Electron Microscope JSM-6390 by Jeol USA Inc was used to visualize the morphology of the particles at x50, x200, and x1500 magnifications at different positions of the sample. To determine the moisture content, a Sartorius Moisture Analyzer MA35M-V equipment was used to determine the moisture content at 100°C using a sample weight of 1.5 to 2 g.

$$\varepsilon = 1 - \left(\frac{\text{Bulk density}}{\text{Particle density}}\right) \tag{5}$$

Material Compaction

The blends of granular material were manually compressed to flat-faced tablets with a diameter of 13 mm and a weight of 1 g using a Carver Hydraulic Press Model 3912 at different compression forces (4, 6 and 8 kgf).

Characterization test included the evaluation of their physical properties (hardness and weight loss percentage) and the evaluation of the material solubility (disintegration time and material solubility time). All compacted products tested followed the acceptance criteria for the weight and thickness variation following the USP <2091> Weight Variation of Dietary Supplements.

Hardness of the compacted material was done using a Varian Benchsaver VK200 Tablet Hardness Tester in kilogram-force (kgf) force unit following the USP <1217> Tablet Breaking Force protocol. For the weight loss percentage, a friability tester Vanderkamp 10809 Model was used following the USP <1216> Tablet Friability protocol.

The behavior of the solubility of the material was analyzed measuring its disintegration time and its solubility time. The disintegration time measurements were performed at 37 °C to satisfy all the requirements established by the USP <701> Disintegration protocol for uncoated tablets using water as a test medium.

The solubility time was defined as the time it took the sample to reach its maximum solubility over a period of time. For this test, we followed USP <711> Dissolution with minor modifications using the SR8 Plus Dissolution Test Station, Auto Plus Maximizer, and Auto Plus MultiFill from Hanson Research. The apparatus configuration has paddles as the method of agitation and was run at a speed of 50 RPM and a distance of 25 ± 2 mm from the bottom of the flask. Dissolution baths were maintained at a temperature of 37 ± 0.5°C, and the media consisted of 900 mL of distilled water (pH = 6.28 ± 0.39). Samples were filtered using a Filter Tip of 70 µm, polyethylene, 1/8 in of Hanson Research.

First, a calibration curve was performed to measure its absorbance (425 - 475 µm) of different dilutions taken from a stock solution of 1.33 g/L. For the general test, a 7 mL sample was taken for 30 minutes (0, 1, 3, 5, 7, 11, 15, 21, and 30 minutes) in triplicate. For each sample, we measured its absorbance using a Genesys 10S UV-Vis Spectrophotometer from ThermoScientific and determined the solubility at the given time using the calibration curve. The relative solubility was calculated using Equation 6 and the final solubility time was reported by the time it took the solution to reach the maximum material relative solubility. The standard value and criteria used for these compacted materials will be discussed in detail in the subsequent sections.

Design of experiment

The study focused on the effect of the raw material type (*Ipomoea batatas* and *Artocarpus altilis*), binder addition (0% and 2% PVP), compression force (4, 6, and 8 kgf), and cutting method (cubes and slices) to establish a range of acceptable options to obtain a compressed product. It was adopted a One-Factor-At-A-Time (OFAT) approach rather than seeking a single optimal response. The experimental design employed a 2^3 x 3^1 factorial with 3 to 4 replicates for the compacted material analysis. The measurements taken were split between physical properties (hardness and weight loss percentage) and material solubility (disintegration time and solubility time), resulting in a total of 288 samples. To assess the statistical difference among the variables, a one-way ANOVA was conducted followed by a Tukey's test to specifically identify significant distinctions, both at a 95% confidence level, using Minitab 21 statistical software version 21.1.

Results

Granular material characterization

Figure 2 depicts the particle size distribution for the blends including PVP as reference. From this, we can see that there is a wide particle size distribution behavior between particles, which can lead to more contact points between the particles and thus increase the hardness of the material when compacted. When analyzing the *A. altilis* granular material, it had a narrower particle size distribution compared to *I. batatas*, hence the particles tend to have more comparable sizes and smaller number of contact points between particles and had a direct influence on the solubility behavior.

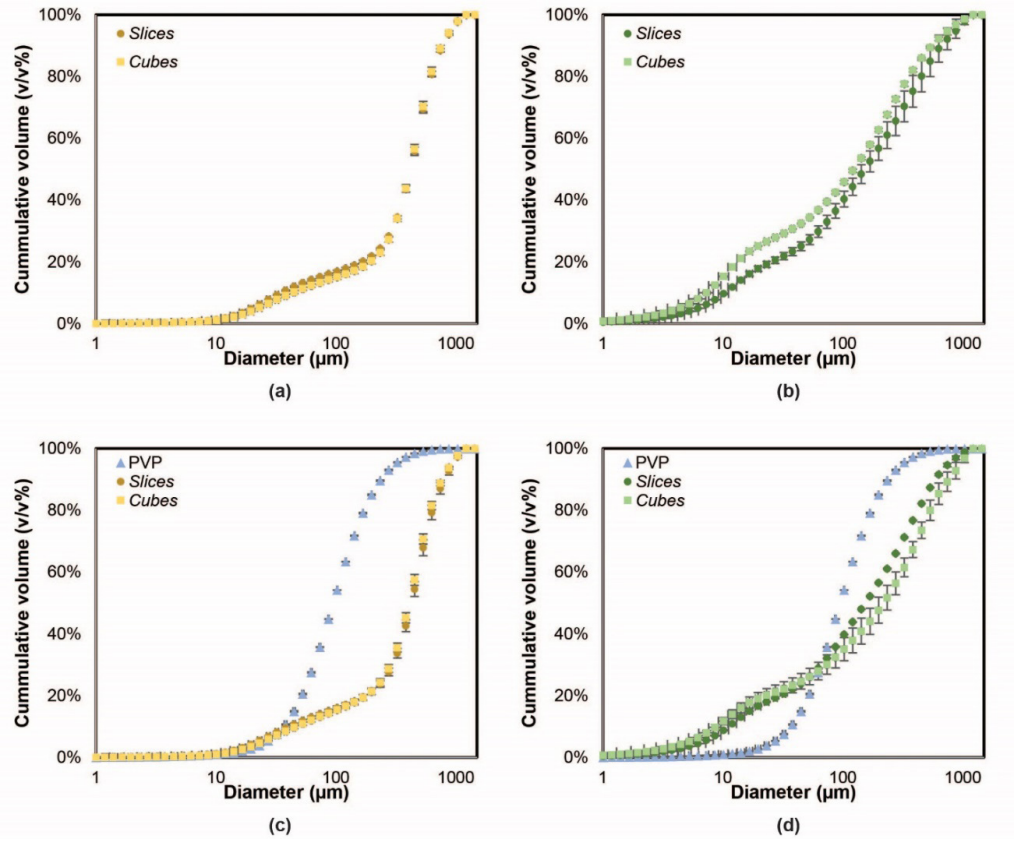

Figure 2. Process flowchart for the compaction of the granular material. Comparison of volumetric particle size distribution of *Ipomoea batatas* and *Artocarpus altilis*. The particle size distribution was examined for different samples comparing the cutting method: (a) *Ipomoea batatas,* (b) *Artocarpus altilis,* (c) *Ipomoea batatas* with 2% PVP, and (d) *Artocarpus altilis* with 2% PVP. Plots which include binder addition also show the PVP particle size distribution. (n=3)

Table 1 shows the D90/D10 and the Span of the blends, where we can see that *A. altilis* mixtures had a wider Span value in comparison to the *I. batatas*. This is related to the higher content of starch in *A. altilis* relative to *I. batatas* based on the values reported by the United States Department of Agriculture (USDA)[19,20]. Also, the D90/D10 ratio corroborates the large difference in size difference, which can lead to a material that tends to segregate.

Table 1. Granular material particle characterizations for *Ipomoea* and *Artocarpus altilis* particles with different binder concentrations and raw material cutting. (n=3-5)

Material	**I. batatas**				**A. altilis**			
Binder (%)	0		2		0		2	
Cut	Slices	Cubes	Slices	Cubes	Slices	Cubes	Slices	Cubes
D50 (µm)	420 ± 30	430 ± 30	420 ± 30	410 ± 20	130 ± 30	150 ± 10	120 ± 40	220 ± 30
D90/D10 (-)	22.3 ± 0.8	17.6 ± 0.5	19.79 ± 0.05	16.6 ± 0.6	64 ± 1	76 ± 3	52.97 ± 0.07	87 ± 5
Span (-)	1.780 ± 0.003	1.73 ± 0.03	1.80 ± 0.03	1.770 ± 0.005	4.3 ± 0.3	4.450 ± 0.004	3.76 ± 0.05	3.5 ± 0.1
Moisture content (%)	9.5 ± 0.5	11.6 ± 0.5	8.89 ± 0.08	12.6 ± 0.2	12.8 ± 0.2	13.0 ± 0.3	12.2 ± 0.4	13.2 ± 0.2
Bulk Density (g/mL)	0.788 ± 0.002	0.754 ± 0.003	0.820 ± 0.002	0.751 ± 0.030	0.540 ± 0.025	0.440 ± 0.002	0.514 ± 0.005	0.43 ± 0.04
Tapped Density (g/mL)	0.65 ± 0.01	0.616 ± 0.007	0.677 ± 0.009	0.62 ± 0.03	0.397 ± 0.005	0.317 ± 0.009	0.400 ± 0.008	0.32 ± 0.03
Particle Density (g/mL)	1.34 ± 0.02	1.424 ± 0.006	1.480 ± 0.001	1.56 ± 0.05	1.59 ± 0.09	1.6 ± 0.1	1.6 ± 0.1	1.63 ± 0.07
Hausner Ratio (-)	1.22 ± 0.03	1.22 ± 0.01	1.21 ± 0.02	1.21 ± 0.01	1.36 ± 0.08	1.39 ± 0.04	1.29 ± 0.01	1.32 ± 0.01
Compressibility index (%)	18 ± 2	18 ± 1	17 ± 1	17.6 ± 0.7	26 ± 4	27 ± 2	22.4 ± 0.8	24.4 ± 0.7
Porosity (-)	0.52 ± 0.01	0.570 ± 0.002	0.540 ± 0.002	0.60 ± 0.01	0.75 ± 0.01	0.80 ± 0.01	0.75 ± 0.01	0.80 ± 0.01

Densities of the materials can be seen in Table 1, where statistical analysis only showed a significant difference between cuts for bulk and tapped density, where slices have a higher density when compared to cubes. Experimental values obtained for both materials go in accordance with the previous values reported[21-25].

Analyzing the Hausner Ratio and the Carr's Index, we see that *I. batatas* particles have a fair flow behavior, while *A. altilis* particles flowed variedly when added to the binder. In this case, it goes from having poor flow behavior to passable flow behavior. This can be attributed to the particle size distribution of the *A. altilis* in comparison to *I. batatas* and the higher particle-particle contact.

The porosity of these granular materials was more than 50% in all cases and can be corroborated by analyzing the morphology of the particles seen in Figure 3. This image shows that the granules are made by a conglomerate of small particles. Also, *I. batatas* particles are more spherical shaped while the *A. altilis* particles are more cubes shaped, thus leading *I. batatas* particles to have a better flow behavior when compared to *A. altilis*.

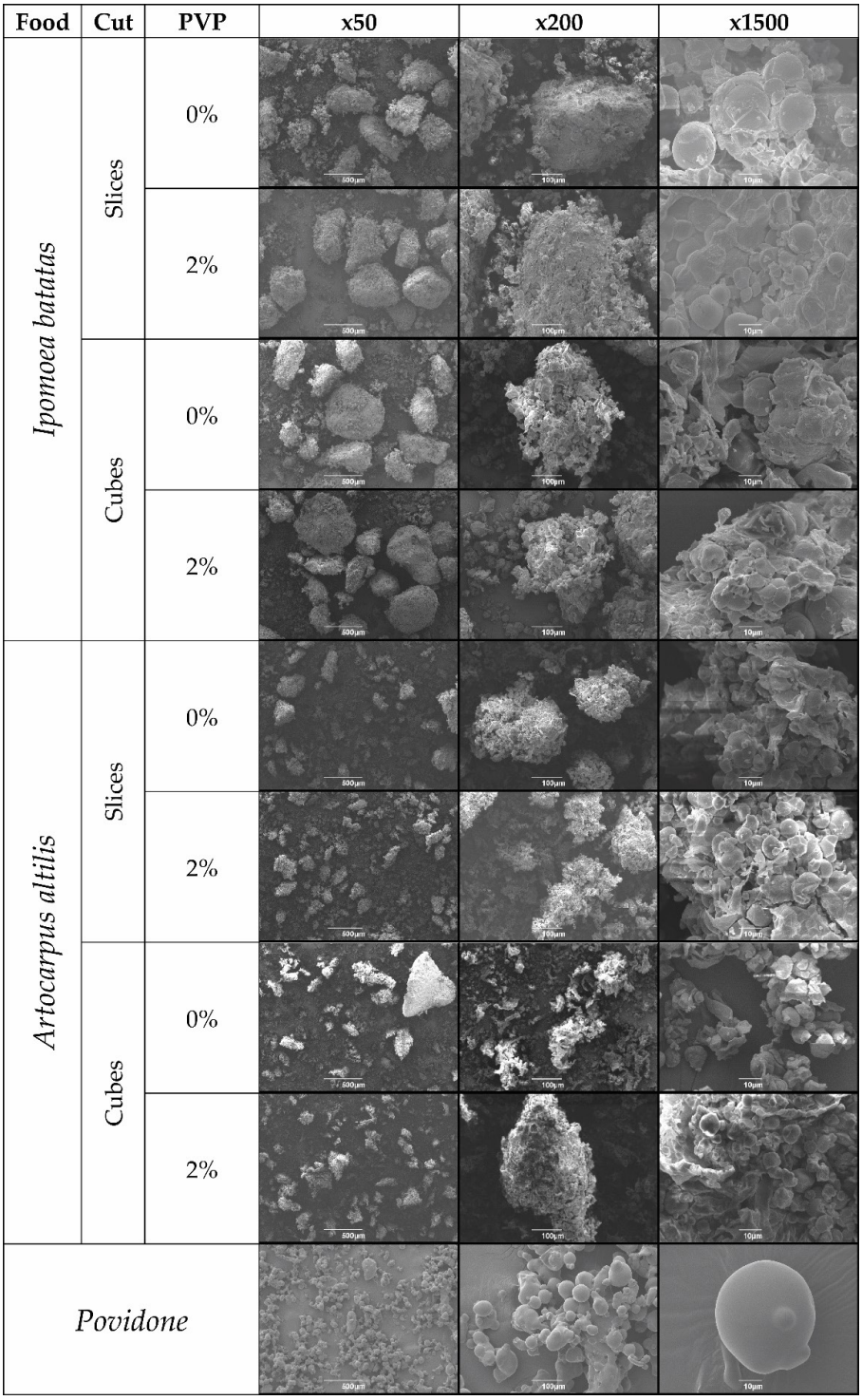

Figure 3. SEM images for the *Ipomoea batatas* and *Artocarpus altilis* formulations at different magnifications.

Physical integrity: Hardness and Friability

This section presents the results, Figure 4, of hardness and friability of the produced tablets as a function of materials composition, binder agent, compression force, and the cutting method of the raw food.

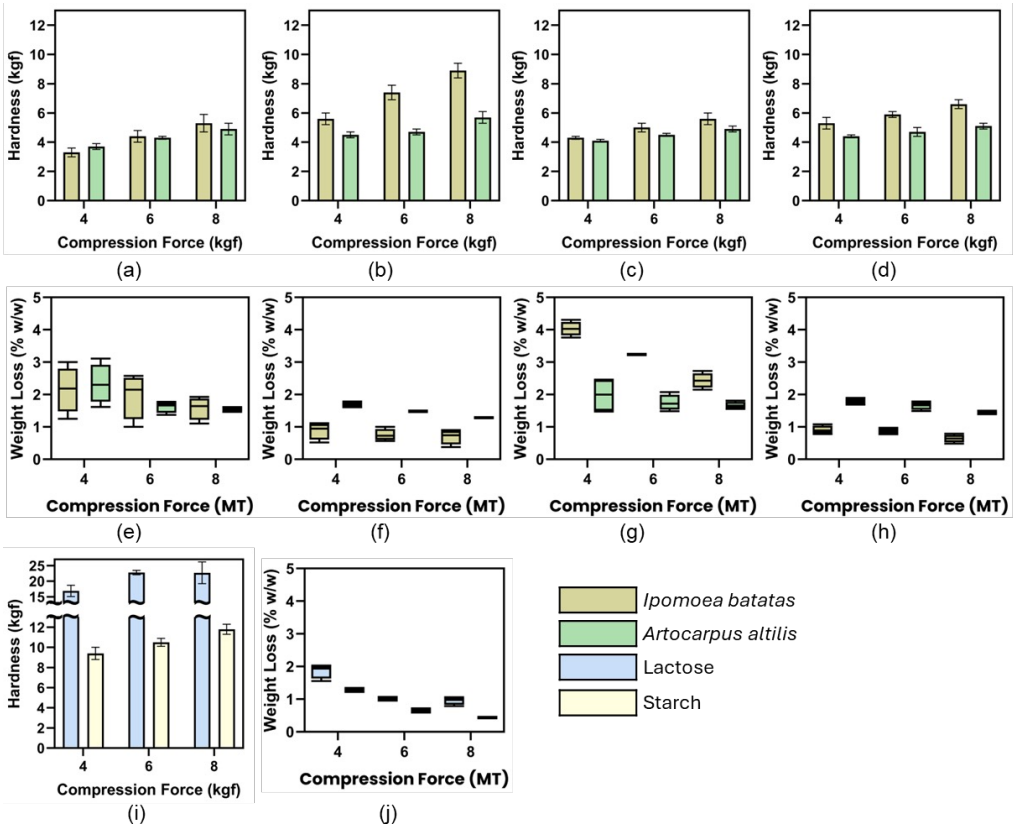

Figure 4. Analysis of the physical integrity of *Ipomoea batatas* and the *Artocarpus altilis*. Hardness was examined for the (a) slice cutting, 0% PVP, (b) slice cutting, 2% PVP, (c) cube cutting, 0% PVP, (d) cube cutting, 2% PVP, and (i) lactose and starch, all at different compression forces. Weight loss percentage of the material was examined for the (e) slice cutting, 0% PVP, (f) slice cutting, 2% PVP, (g) cube cutting, 0% PVP, (h) cube cutting, 2% PVP, and (j) lactose and starch, all at different compression forces. Data represents the average of n= 3-4 runs.

Materials effects

The hardness of the *I. batatas* compacted material was between 0.9 to 1.1 times than those of *A. altilis*. Based on the USDA database as reference, the difference in this behavior can be attributed to the carbohydrate components (i.e., starch, fiber, and sugars) of the materials. *I. batatas* has more than 1.5 times fiber, more than 2.5 times sugar, and less than 0.85 times starch contents when compared to the *A. altilis*[19,20]. As described in multiple studies[26-28], these components have a direct impact on the cohesion and properties of the compacted structures. Sugar components can conceivably make the *I. batatas* more malleable and hence more compressible and the fiber ones would increase the cohesion, which in combination will make stronger particle-particle bonds.

Binder addition

The binder increased the hardness of the *I. batatas* tablet between 1.2 and 1.7 times, while for *A. altilis* increased up to 1.2 times when compared to the behavior without binder. When comparing with the values without the binder, the addition of the binder lowered the loss percentage of *I. batatas* between 60 and 80%, while for *A. altilis*, the reduction was between 10 to 30%. The binder agent significantly increased the compacted material hardness when compared with the materials without binder, demonstrating the role of binders in increasing proportionately the mechanical strength. As for weight loss percentage, *I. batatas* with binder were below 1% weight loss percentage, achieving the target physical properties. *A. altilis* with binder, while slightly above this limit, remained below 2%, confirming their suitability for pharmaceutical applications. This highlights the effectiveness of the binder in minimizing material loss during the compaction of the material.

Compression force

The effect of the compression forces on the hardness of the material followed the expected behavior in all runs. However, the results for weight loss percentage indicate that there was no significant difference with the compression force, except for the *I. batatas* that were cut into cubes with 0% of binding material. Although results were not statistically different, these depict that an increase in compression force leads to a decrease in weight loss percentage. Both behaviors can be influenced by the size distribution of particles in the sample impacting the capacity of the material to be compacted and its overall hardness. This suggests that higher compression forces contribute to more compacted structures with reduced porosity, resulting in decreased material loss during compaction.

Cutting method

Analyzing the cutting method (surface area change) of the raw foods before the drying process, it did not have a significant difference in either the hardness or the friability values. Even though particle morphology may have an impact on the final properties of the compacted material and the particle arrangement, all underwent a milling process before compression, which resulted in them having similar geometries and thus reducing the impact of particle morphology on the final properties.

Comparison with typical material

Comparing the overall experimental hardness values with the control values, as seen in Figure 4 (e), lactose showed 4.1-fold greater hardness, while the starch showed 2.1-fold greater hardness under these experimental conditions. The higher hardness of lactose could be attributed to the crystalline structure of lactose, which typically results in stronger formations while the hardness of starch can be attributed to the higher presence of amylose and amylopectin molecules that could cause the hydration and swelling behavior upon compression thus forming a more cohesive and rigid matrix. The hardness value of this experimental starch is similar to ranges reported in the literature using starch extracted from cassava[29].

When comparing the weight loss percentage values in Figure 4 (j), we see that the experimental values exhibit 1.3-fold and 2.2-fold greater losses than the lactose and starch, respectively, under these experimental conditions. This indicates that unmodified food compacted materials are affected by mechanical stress compared to the commercially available lactose and starch. The starch values at a compression force of 8 kgf are similar to those reported in the literature using starch extracted from cassava[29].

Material solubility: Disintegration and Solubility time

The material solubility or availability in solution is represented by the disintegration time and the solubility time tests. These are two of the standard tests that can be done to understand how fast a desired ingredient of the overall blend is available in solution. In this study, the interest is the starches of the *I. batatas* and *A. altilis*. The results are presented as a function of material composition, binder agent, compression force, and the cutting method of the raw food. As shown in Figures 5 (a) – (d), there was a significant difference in the disintegration time between the *I. batatas* and *A. altilis*, ranging from 8 to 15 minutes and 2.5 to 5 minutes, respectively.

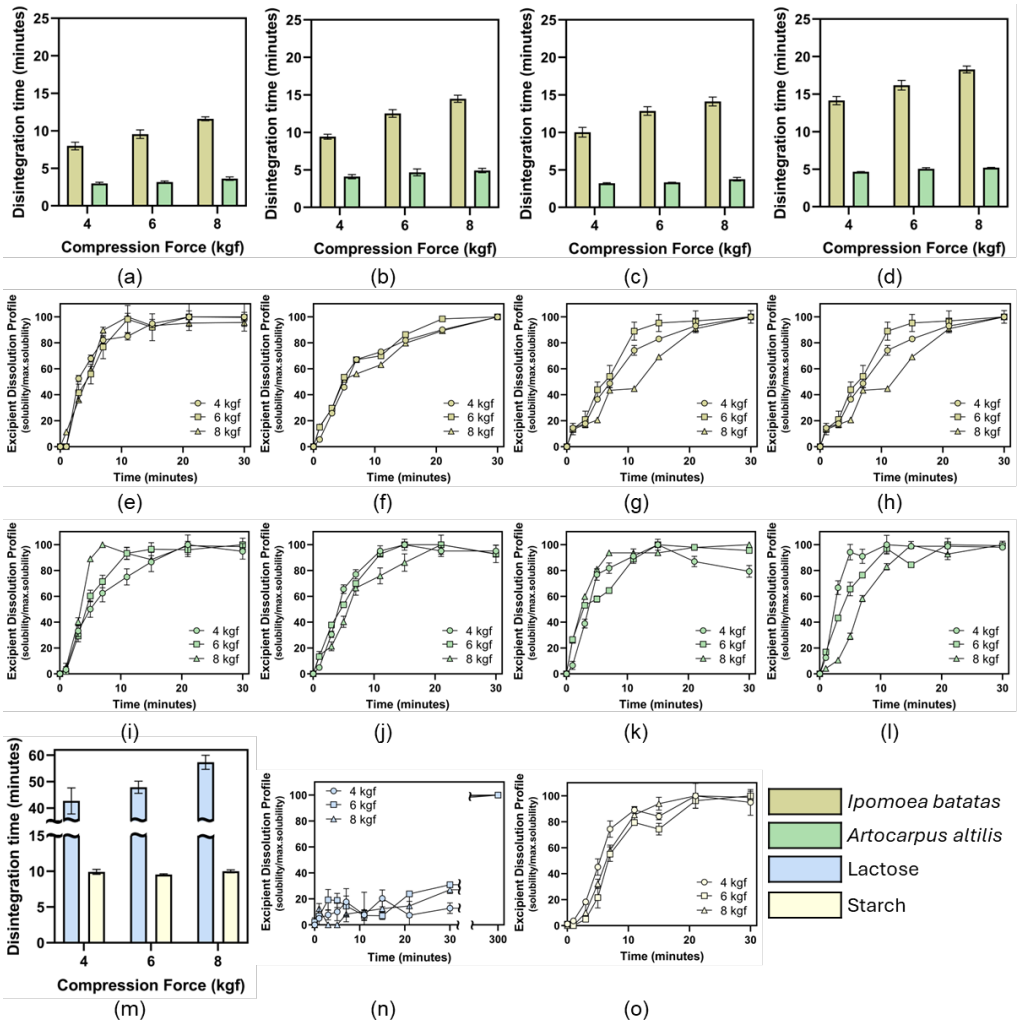

Figure 5. Analysis of the solubility performance of *Ipomoea batatas* and the *Artocarpus altilis*. The disintegration time was examined for the (a) slice cutting, 0% PVP, (b) slice cutting, 2% PVP, (c) cube cutting, 0% PVP, (d) cube cutting, 2% PVP, and (m) lactose and starch, all at different compression forces. Solubility time was examined by measuring the time for reaching the maximum excipient relative solubility for the *Ipomoea batatas* at (e) slice cutting, 0% PVP, (f) slice cutting, 2% PVP, (g) cube cutting, 0% PVP, and (h) cube cutting, 2% PVP, the *Artocarpus altilis* at (i) slice cutting, 0% PVP, (j) slice cutting, 2% PVP, (k) cube cutting, 0% PVP, and (l) cube cutting, 2% PVP, (n) lactose, and (o) starch, all at different compression forces. Data represents the average of n= 3-4 runs.

Materials effect

The significant effect of material composition on disintegration time seen in Figure 5 (a)-(d) is attributed to the higher starch content in *A. altilis* compared to *I. batatas*, which promotes faster breakdown and disintegration of the tablets, as reported in previous studies[19,20,30,31]. Also, physical properties are reported to play a role in the observed differences, since *A. altilis* had less hardness values and greater weight loss percentage in comparison to *I. batatas*[32,33]. As for the materials solubility time, *I. batatas* exhibited a range of 14 to 18 minutes while *A. altilis* exhibited a range of 5 to 9 minutes. This difference

can be related to the fiber content and, since *I. batatas* has a 1.5 times higher reported content in comparison with *A. altilis,* this may slow the material release.

The narrowed PSD of *A. altilis* caused a more porous granule due to the particle-particle interaction, which allowed a faster disintegration and solubility time compared to *I. batatas*, which resulted in a more rigid, stable granule that resulted in a higher resistance to disintegration and a slower material solubility rate.

Binder addition

Adding a binder to the materials presented a significant difference between *I. batatas* and *A. altilis*, increasing the disintegration time for all the runs. As for the materials solubility time, there was only a significant difference for compacted materials made from the slice cut at 6 and 8 kgf. This is in accordance with what was expected, where adding a binder increased the solubility time at those compression forces. Even though PVP is freely soluble in an aqueous solution and does not directly influence the disintegration or solubility time, it aids the material performance with an adhesive bond between particles, which results in a slower disintegration times as reported on previous researches[34].

Compression force

The compression forces applied during the granular material compaction exhibited a significant effect on the disintegration time of all the *I. batatas* runs, whereas it only showed a significant effect on the 4 and 8 kgf for the *A. altilis* runs. Overall, it was observed that higher compression forces led to longer disintegration times. In terms of material solubility time, there was a notable difference between the results when varying between 6 and 8 kgf, where an increase in compression force resulted in a longer solubility time.

Cutting method

The two methods of cutting the raw material did show a statistically significant difference in the disintegration time of *I. batatas* and the material solubility time of *A. altilis*. Regarding disintegration times, the use of cube cuts of *I. batatas* resulted in longer disintegration times when compared with slice cuts. For the material solubility time, *A. altilis* slice cuts were seen to increase the solubility time when compared with the cubed cut. Despite the different cutting techniques employed, the moisture content of the compressed mixtures was roughly the same since the materials were extracted from the drying oven upon reaching the desired final moisture level. Hence, the actual effect of the cut should not relate to the behavior of the final product, but rather to the drying time of the materials to be milled afterward. In fact, slices cuts were 1.57 times faster than cubes cuts during the drying of the material, which incurs operational costs.

Comparison with typical materials

Comparing the disintegration times with lactose and starch compacted products in Figure 5 (e), lactose had a disintegration time 5.9-fold higher than our experimental values, while the disintegration time for the starch was 1.2-fold higher than our experimental runs under our conditions. The higher disintegration time of lactose compared to ours can be attributed to differences in material composition, particularly the crystalline structure of lactose, its lower solubility, and its brittle nature, which results in slower disintegration when subjected to high compression forces[35-37]. The starch value is similar to values reported in the literature, falling within these ranges using starch extracted from cassava[29].

When comparing the material's solubility time values of starch in Figure 5 (o), we observe that these times are similar to the results obtained under these experimental conditions. This may indicate that despite being chemically unmodified, the starch from *I. batatas* and *A. altilis* still predominates the overall behavior. Since the lactose material solubility time values exceeded the 30-minute reading time, these were not considered for this analysis.

Comparison with typical acceptance ranges of uncoated compressed materials

To validate the experimental values, we considered the industry-standard ranges of one of the most highly regulated sectors, the pharmaceutical industry, which serves as a benchmark for quality assurance. This comparison not only aids credibility to the gathered data, but also facilitates the assessment of product performance against established norms. In this context, we focused on evaluating the typical acceptance ranges of uncoated tablets, particularly emphasizing guidelines from the US Pharmacopeia (USP) and the Food and Drug Administration (FDA).

Typical hardness for oral tablets ranges from 3 to 10 kgf, according to referenced literature[38-41]. When comparing our findings with this range, it was observed that the hardness values of both *I. batatas* and *A. altilis* exceeded the lower acceptance limit by 1.1 to 3.0 and 1.2 to 1.9 times, respectively. As for weight loss percentage, these value should not exceed 1.0% to be considered as acceptable, as indicated in USP guidelines[42]. Our results demonstrated the *I. batatas* blended with binder were below the 1% weight loss percentage acceptance value, while the *A. altilis* with binder were over, but below 2%.

Considering disintegration time, it is desired that tablets disintegrate completely within a maximum of 30 minutes, according to USP guidelines[43]. All compacted material tested in this study met this requirement and had a constant dissolution time. Regarding material solubility time, compliance with FDA recommendations for immediate-release mentions that 80% of the material should dissolve within 30 minutes[44]. In addition, immediate-release tablets have been reported to fully dissolve upon exposure within 2.5 to 10 minutes[45]. When comparing our experimental material solubility time, all the *A. altilis* were between this acceptance range while the I. batatas were *1.3 to 1.9* times higher than the above reported value, but still are below the 30 minutes range. These comparative analyses underscore the suitability of chemically unmodified granular materials from *I. batatas* and *A. altilis* for compaction, highlighting their suitability to establish a highly regulated industry standard.

Conclusions

This study demonstrates the suitability of using granular material of chemically unmodified local *I. batatas* and *A. altilis* to create tablets. *Ipomoea batatas* were spherical with a D50 of 420 µm and a porosity ranging from 50% to 60%, exhibiting fair flow behavior and average compressibility. *Artocarpus altilis* particles, irregular in shape with a D50 of 120–200 µm and porosity of 75% to 80%, displayed passable flow and high compressibility, forming agglomerates of small particles.

The addition of a binder agent and different tablet compression forces influenced the physical properties and materials solubility of the tablets. The addition of a binder was a key factor impacting all the tablet measured properties, where it lowered the weight loss percentage, and increased the hardness, disintegration time, and solubility time as expected. Also, the effects of the compression forces were consistent with expectations, as increased forces correlated with enhanced physical properties and material solubility of the tablets. Upon examining the food materials, it was seen that the carbohydrate composition of the material was one of the main causes for this difference in results, especially for the material solubility time values. The cutting technique for the raw food did not affect the final behavior of the product, rather in the manufacturing drying time of the material.

This work confirms that these food products can be employed to form tablets without the need for special treatments, such as extractions, making the tablets more affordable material. By understanding the behavior of the untreated material in these tests, we can better predict tablet interactions when adding APIs in future formulations. Since the food products were dried, milled and compacted into tablets without intermediate extraction of ingredients, this strategy would represent an additional savings to the overall process. Additionally, this product could be an alternative in various applications, such as new drug formulations, supplements, and hypoallergenic alternatives, providing a new option for those who have a gastrointestinal disease or are diabetic.

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