Assessing the Effects of Extraction Methods on the Properties of Chayote (*Sechium edule*) Tuber Starch

Abstract

This study investigates the effect of different starch extraction methods on the yield and properties of chayote (*Sechium edule*) tuber starch. Chayote, a tuberous plant rich in starch, was subjected to both physical and chemical extraction methods, with treatments including water, sodium hydroxide, and sodium metabisulfite. The study evaluated for starch yield, particle size, bulk density, flowability, pH, amylose, amylopectin content, water and oil absorption capacity, and starch paste clarity. The highest starch yields were obtained from water (21.62%), sodium hydroxide (21.17%), and sodium metabisulfite (21.19%) treatments. Starch clarity was highest in treatments using sodium metabisulfite, with clarity values up to 73.26%, indicating potential for high transparency. Treatment T7, which used sodium metabisulfite, yielded the highest amylopectin content (70.46%), making it ideal for applications requiring low retrogradation, such as edible coatings. The study concludes that chayote tuber starch shows great potential for industrial applications, with the extraction method significantly affecting its physical and chemical properties. Treatment T7 is recommended for optimal starch yield, clarity, and amylopectin content, making it suitable for use in coatings and food formulations requiring flexibility and stability.

1. Introduction

Chayote (*Sechium edule*) is a perennial climbing plant native to Mexico and Latin America, domesticated by the Aztecs and Mayas (Coronel *et al.* 2017). It is widely cultivated in tropical and subtropical climates, with major producers including Mexico, Costa Rica, Brazil, and the Dominican Republic (Vieira *et al.* 2019). In India, chayote is grown in states like Tamil Nadu, Karnataka, West Bengal, and the North-eastern region, with Mizoram leading production (Rai *et al.* 2006; Sanwal 2008). Known by various names, including Chow-Chow, Isqush (Nepali), and Piskut (Khasi), chayote is used primarily for consumption, with its fruit, leaves, stalks, and tubers all being edible (Hernandez-Uribe *et al.* 2011).

Chayote tubers, produced after the first year of growth, are rich in starch and fiber, with tubers weighing 2.1–6.5 kg (Jimenez *et al.* 2007). The tubers contain 25.8% total solids, of which 59% is starch, and can be extracted with a purity of 90% (Cotonieto-Morales *et al.* 2015). Similar in structure to potato and cassava, chayote starch is a viable alternative to these starch sources (Shiga *et al.* 2015).

Starch extraction typically involves grinding the tubers, separating starch through sieving, and removing water via settling or centrifugation (Daiuto *et al.* 2005). Various methods, including physical, chemical, and enzymatic, affect starch's properties, with enzymatic extraction being time-consuming and costly (Singh *et al.* 1997). Daiuto *et al.* (2005) found better starch recovery using oxalic acid/ammonium oxalate (18%) compared to water, pectinase, or NaOH treatments (10%).

Jimenez *et al.* (2007) and Hernandez-Uribe *et al.* (2011) isolated chayote starch using physical methods, showing comparable starch content to potatoes and a purity level above 98%. Different extraction methods influence the yield and properties of starch, as seen in studies on sweet potatoes (Babu and Parimalavalli 2014). Recent studies suggest sodium metabisulfite improves starch recovery and whiteness (Kale *et al.* 2017; Xu *et al.* 2018). This study aims to compare the yield, and physical and chemical properties of starch extracted from chayote tubers using both physical and chemical methods.

2. Materials and Methods

Medium-sized, undamaged and fresh chayote tubers were purchased from the local market in Ranipool, Sikkim. Sodium metabisulphite was purchased from a chemical supplier in Siliguri, India

2.2 Physical method of extraction

The method described by Aila *et al.* (2013) was followed for starch extraction. The chayote tuber was washed, peeled, and cut into 2×2 cm cubes. The cubes were blended with water (1:1, tuber: water) ratio for 2 minutes at low speed. The homogenate was sieved through a 250-micron sieve, washed until the water ran clear, and left to settle for 2 hours. The settled starch was drained, dried in a hot air oven at 40±5ºC overnight, ground into a fine powder, sieved through a 150-micron sieve, and stored in an airtight container.

2.3 Chemical method of extraction

The method described by Neeraj *et al. (*2021) was followed the chemical extraction method. According to the method, chayote tuber cubes were soaked for 10 minutes separately in different concentrations of sodium hydroxide (0.1%, 0.25%, 0.5%, 0.75%, and 1%) and sodium metabisulphite (0.01%, 0.025%, 0.05%, 0.075%, and 0.1%) solutions. The cubes were then macerated into slurry, sieved through a 250-micron sieve, and washed until the water ran clear. The slurry was left undisturbed for 2 hours to allow starch to settle, then excess water was drained, and the process repeated. The accumulated starch was dried overnight at 40±5ºC, ground into a fine powder, sieved through a 150-micron sieve, and stored in an airtight container.

2.4 Starch yield

The amount of starch extracted from a given quantity of raw materials is known as starch yield and typically expressed as a percentage. The starch yield was calculated as below:

$$\boldsymbol{Starch\ yield}\ (\%) = \frac{Weight\ of\ extracted\ starch\ (g)}{Weight\ of\ peeled\ tuber\ taken\ (g)} \times 100$$

2.5 Physical properties

The physical properties of starch such as particle size, bulk density was determined as described by Bayor *et al.* (2013). The flow ability was determined by measuring the angle of repose as described by Alyami *et al.* (2019).

2.6 Chemical properties

Total starch content was determined by the method described by Dubois *et al.* (1956) and the total starch content was calculated using the following formula:

$$\boldsymbol{Total\ starch}\ (\%) = \frac{(Abs - intercept \times dilution\ factor \times volume \times 0.9)}{(Weight\ of\ sample \times slope \times 10000)}$$

Where, abs= absorbance

Amylose content was determined by the method reported by Babu and Parimalavalli (2014), as cited in Williams *et al.* (1958). The amylose content was calculated using the following formula:

$$\boldsymbol{Amylose\ content}\ (\%) = 3.06 \times A \times 20$$

Where, A = Absorbance value

Amylopectin content was calculated using following formula:

$$\boldsymbol{Amylopectine\ content}(\%) = (\%\ total\ starch - \%\ amylose\ content)$$

The pH of the starch sample was determined by digital pH meter as described in Wijesinghe and Gunathilake (2020). Water and Oil Absorption Capacity of chayote tuber starch were determined by the method described by Abbey and Ibeh (1988); Babu and Parimalavalli (2014). Clarity of starch paste was measured using spectrophotometer as the method described by Sit et al. (2014).

2.7 Statistical analysis

The data were the average of three determinations and presented as mean ± SD. The observation taken for various treatments were subjected to individual Completely Randomized Design (CRD) analysis. The difference among the means were determined by comparing them with Critical Difference (CD) value at ($p<0.05$).

3. Results and Discussions

Table 1: Physical properties of chayote tuber starch extracted by different treatments

Treatments		Particle size(μm)	Bulk density (g/ml)	Flow ability
Physical method				
T1	Water (1:1)	95.93 ± 0.56^{def}	0.44 ± 0.02^{fg}	56.73 ± 0.44^{a}
Chemical method				
T2	NaOH (0.1%)	97.22 ± 0.81^{abc}	0.43 ± 0.01^{fghi}	54.39 ± 1.34^{cd}
T3	NaOH (0.25%)	97.46 ± 0.84^{ab}	0.42 ± 0.01^{ghij}	55.55 ± 0.32^{abc}
T4	NaOH (0.5%)	96.35 ± 0.26^{bcde}	0.45 ± 0.03^{f}	56.32 ± 0.20^{ab}
T5	NaOH (0.75%)	97.61 ± 0.22^{a}	0.44 ± 0.01^{fgh}	50.76 ± 1.24^{f}
T6	NaOH (1.0%)	96.80 ± 1.36^{abcd}	0.40 ± 0.01^{j}	49.64 ± 1.21^{fgh}
T7	$Na_2S_2O_5$ (0.01%)	91.46 ± 0.15^{ij}	0.49 ± 0.01^{bcd}	54.78 ± 1.85^{bcd}
T8	$Na_2S_2O_5$ (0.025%)	95.24 ± 0.98^{efg}	0.50 ± 0.01^{abc}	48.91 ± 1.36^{fgh}
T9	$Na_2S_2O_5$ (0.05%)	91.69 ± 0.75^{i}	0.51 ± 0.01^{ab}	50.28 ± 0.15^{fg}
T10	$Na_2S_2O_5$ (0.075%)	91.02 ± 0.39^{ijk}	0.52 ± 0.01^{a}	45.63 ± 1.30^{j}
T11	$Na_2S_2O_5$ (0.1%)	94.89 ± 0.75^{g}	0.50 ± 0.01^{abcd}	46.13 ± 1.46^{j}
CD @ 5%		1.242	0.022	1.926
CV (%)		0.77	2.46	2.20

Note: The values are the means of 3 replicates ± standard deviation. Means in the columns that share the same lowercase letter for each determination are not significantly different ($p<0.05$)

3.1 Effect of different starch extraction methods on physical properties of chayote tuber starch

The particle size, bulk density, and flow ability of starch extracted by different methods are shown in Table 2. Particle size ranged from 91.02 to 97.61 μm, with significant differences

($p<0.05$). Larger sizes were observed in treatments T5, T3, and T2 (97.61, 97.46, and 97.22 µm), while smaller sizes appeared in T10, T7, and T9 (91.02, 91.46, and 91.69 µm). Bayore *et al.* (2013) reported similar results for sweet potato starch. Previous studies on chayote starch reported smaller granule sizes (7 to 50 µm by Jimenez *et al.* 2007 and 10 to 25 µm by Hernandez-Uribe *et al.* 2011). Differences may be due to variations in origin, cultivar, or extraction and measurement methods.

Bulk density is crucial for powders, as it determines how much starch can be incorporated into a solution, affecting coating thickness and consistency. In this study, bulk density ranged from 0.40 to 0.52 g/ml, with significant differences ($p<0.05$). The lowest value was 0.40 g/ml (T6), and the highest was 0.52 g/ml (T10). Bulk density is inversely related to particle size larger particles result in lower bulk density, similar to findings by Kale *et al.* (2017) for sweet potato starch.

The flow ability of starch was assessed by measuring the angle of repose, which ranged from 45.63º to 56.73º, with significant differences ($p<0.05$). The lowest angle was 45.63º (T10), while the highest were 56.73º (T1) and 56.32º (T4). Finer particles, with a higher surface area-to-volume ratio, tend to have steeper angles due to stronger cohesive forces, causing the particles to stick together. Irregularly shaped particles also have a higher angle of repose than smooth ones. Jimenez *et al.* (2007) and Hernandez-Uribe *et al.* (2011) noted chayote starch's mixed particle shapes, contributing to higher angles. According to Mullarney *et al.* (2011), an angle of repose above 45º indicates poor flow ability. Chayote starch showed poor flow ability, with an angle of repose between 45.63º and 56.73º.

3.2 Effect of different starch extraction methods on chemical properties of chayote tuber starch

The chemical properties of chayote starch, including total starch, amylose, amylopectin, pH, water and oil absorption, and paste clarity, are shown in Table 3. Total starch content ranged from 83.67% to 95.81%, with significant differences ($p<0.05$). Treatment T8 had the lowest starch content (83.67%), while T7 had the highest (95.81%). Water and sodium metabisulfite treatments resulted in higher starch purity compared to sodium hydroxide. Similar findings were reported by Hernandez-Uribe *et al.* (2011) for chayote and potato starch. Kale *et al.* (2007) noted NaCl treatments improved starch purity by reducing residual protein, while this study found sodium metabisulfite (T7) yielded the highest starch content, possibly due to its bleaching effect. Varietal and extraction method differences also influence starch content (Julianti *et al.* 2018).

The amylose content of chayote starch varied from 24.88% to 26.88%, with the lowest in treatment T10 and the highest in T8 (Table 3). Previous studies reported different values, such as 12.9% (Jimenez *et al.* 2007) and 26.3% (Hernandez-Uribe *et al.* 2011), likely due to cultivar differences and testing methods. Amylose content in tuber starches typically ranges from 15% to 38% (Hoover *et al.* 2001). High-amylose starches are valued for their strong gelling properties, making them ideal for bakery items, coatings for fried foods, and edible films for preserving food products.

Amylopectin content in the starch ranged from 56.05% to 70.46%, with significant differences ($p<0.05$). Treatment T8 had the lowest (56.05%) and T7 the highest (70.46%) amylopectin content. Jimenez *et al.* (2007) found 87.1% amylopectin in chayote starch, noting that an amylose-to-amylopectin ratio below 0.5 indicates predominance of amylopectin, which was also observed in this study. Neeraj *et al.* (2021) reported similar findings for potato starch, with amylopectin content ranging from 79.7% to 88.6%, influenced by extraction methods. High amylopectin starches form gels with low retrogradation tendencies (Beynum and Roles 1985).

The pH of chayote starch ranged from 4.66 to 8.10, with significant differences ($p<0.05$). Treatments T11 and T9 had the lowest pH (4.66 and 4.93), while T4 and T1 had the highest (8.96 and 8.10). Jimenez *et al.* (2007) similarly reported a pH of 8.12 for chayote starch extracted with water. Higher pH values indicate greater ionization, enhancing water interaction with amylopectin and amylose. The lower pH is due to the use of sodium hydroxide in the extraction process, contributing to its alkalinity.

Water Absorption Capacity (WAC) measures starch's ability to absorb water and swell, influencing food texture, consistency, and stability (Hannington *et al.* 2020). In this study, WAC ranged from 0.86 to 1.34 ml/g, with the highest in T4 (1.34 ml/g) and the lowest in T9 (0.86 ml/g). Chayote tuber starch’s high WAC indicates its hydrophilic nature, essential for food and industrial applications. This property is due to the hydroxyl groups in amylose and amylopectin, which form hydrogen bonds with water, enhancing water absorption and swelling (Moorthy 2002).

Oil Absorption Capacity (OAC) is a key property for food texture, mouthfeel, and flavour retention, indicating starch’s emulsifying potential (Ajatta *et al.* 2016). In this study, OAC ranged from 0.99 to 1.36 ml/g, with the highest in T1 (1.36 ml/g) and lowest in T10 (0.99 ml/g). While OAC is influenced by amylose content, no direct link has been established. Tuber starches generally have OAC between 0.962 and 1.152 g oil/g starch (Azima *et al.* 2020). Understanding OAC helps optimize chayote starch for specific food applications.

Starch paste clarity indicates the transparency of the gel after gelatinization, a key factor for food and textile industries (Moorthy 2002). In this study, clarity ranged from 19.53% to 73.26%, with T1 showing the lowest (19.53%) and T10, T11, and T7 the highest (73.25%, 73.26%, and 67.91%) (Table3). Variations result from isolation methods and interactions between phosphate groups and sodium ions, affecting light transmittance (Bello-Perez and Irapuato 1996). Higher clarity can also be linked to fewer phenolic compounds in chayote, which keeps starch clean and white (Shiga *et al.* 2015).

4. Conclusion

Starch extraction from tubers is simpler compared to other sources, with cassava, potato, and maize starch being widely used industrially. There is potential to explore new tuber starches with similar properties. In this study, treatments T1 (21.62%), T4 (21.17%), and T7 (21.19%) gave higher starch yields, while treatments T7 (67.91%), T10 (73.25%), and T11 (73.26%) showed the highest paste clarity. Treatment T7 also had high amylopectin content, which reduces retrogradation, maintaining flexibility in coatings over time (Beynum and Roles 1985). Based on yield, clarity, and amylopectin, treatment T7 is better for chayote starch extraction.

Table 2: Chemical properties of chayote tuber starch extracted by different treatments

	Treatments	Total starch content (%)	Amylose content (%)	Amylopectine content (%)	pH	Water absorption capacity(ml/g)	Oil absorption capacity(ml/g)	Clarity of starch paste (%)
				Physical method				
T1	Water (1:1)	94.70±0.39	25.85 ± 0.43^{bcde}	68.55±0.28	8.10±0.04	1.09 ± 0.07^{a}	1.36±0.04	19.53±0.01
				Chemical method				
T2	NaOH (0.1%)	87.42 ± 0.38^{bc}	26.53 ± 0.30^{ab}	61.44 ± 0.04^{b}	7.78±0.04	1.03 ± 0.05^{abc}	1.16 ± 0.08^{abc}	38.82±0.00
T3	NaOH (0.25%)	90.28±0.28	26.10 ± 0.04^{bcdef}	64.28±0.10	7.88±0.03	1.03 ± 0.02^{abcdf}	1.12 ± 0.08^{bcde}	28.51±0.01
T4	NaOH (0.5%)	89.28±0.23	25.95 ± 0.01^{bcdefg}	63.54±0.28	8.96±0.06	1.04 ± 0.03^{ab}	1.17 ± 0.10^{ab}	63.64±0.55
T5	NaOH (0.75%)	87.34 ± 0.07^{bc}	25.72 ± 0.27^{efgh}	61.39 ± 0.10^{bc}	7.16±0.03	0.99 ± 0.06^{abcde}	1.23 ± 0.06^{a}	50.33±0.02
T6	NaOH (1.0%)	93.50 ± 0.10^{a}	25.48 ± 0.11^{ghi}	68.09 ± 0.08^{a}	7.60±0.01	1.34 ± 0.13^{e}	1.04 ± 0.11^{dfghi}	60.39±0.01
T7	$Na_2S_2O_5$ (0.01%)	95.81±0.09	25.24 ± 0.10^{hij}	70.46±0.22	6.30±0.03	0.95 ± 0.06^{defgh}	1.16 ± 0.11^{abcd}	67.91±0.01
T8	$Na_2S_2O_5$ (0.025%)	83.67±0.06	26.88 ± 0.72^{a}	56.05±0.06	6.97±0.08	0.91 ± 0.08^{efghi}	1.09 ± 0.07^{cdefg}	55.60±0.01
T9	$Na_2S_2O_5$ (0.05%)	87.58 ± 0.29^{b}	26.33 ± 0.23^{abcd}	61.36 ± 0.13^{bc}	4.93±0.02	0.86 ± 0.07^{fgi}	1.14 ± 0.07^{abcde}	46.55±0.02
T10	$Na_2S_2O_5$ (0.075%)	93.34 ± 0.29^{a}	24.88 ± 0.68^{j}	68.12 ± 0.11^{a}	6.44±0.06	0.97 ± 0.05^{bcdefh}	0.99 ± 0.02^{ghi}	73.25 ± 0.04^{a}
T11	$Na_2S_2O_5$ (0.1%)	94.17±0.17	26.39 ± 0.35^{abc}	67.46±0.04	4.66±0.04	0.97 ± 0.05^{cdefg}	1.05 ± 0.03^{cdefgh}	73.26 ± 0.03^{a}
	CD @ 5%	0.413	0.597	0.261	0.074	0.112	0.125	0.284
	CV (%)	0.27	1.36	0.24	0.63	5.95	0.63	0.32

Note: The values are the means of 3 replicates ± standard deviation. Means in the columns that share the same lowercase letter for each determination are not significantly different (α<0.05)

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