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Explores the study of different isolation and quality improvement methods of starch: A Review

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ABSTRACT

Starch is the most widely applicable food ingredient, offering innumerable applications in the food industry due to its high technological value. The main purpose of this review is to gather information from previous works on starch isolation and its characterization from different food sources, such as cereals, tubers, fruits, and vegetables. However, challenges in starch extraction, such as yield efficiency and purity, as well as the variations in properties depending on the source, complicate the standardization of processes. Moreover, the effect of various methods in improving starch, such as fermentation and microfluidization, has been reviewed. Fermentation enhances properties like paste clarity, water absorption capacity, and solubility of starch. Microfluidization improves the functional properties of starches by applying high pressure, which may be beneficial for new product development. This review contributes to understanding the advancements in starch modification techniques and their potential to enhance product development in the food industry.

Keywords: *Starch isolation and extraction, Food-based starch sources, Quality improvement, Product development, Fermentation and Microfluidization*

1. Introduction

There are various type of staple food such as cassava, rice, maize (corn), potato, yam and wheat in which starch is found abundantly. It is made up of large amount of polymer of α-glucose and it consists of amylose and amylopectin. Amylose is a water soluble long unbranched linear chain with a D-glucopyranosyl unit held together by a α (1-4) glycosidic linkage. Amylopectin is a highly branched, water-insoluble polysaccharide made up of chains of D-glucose units linked by α-(1→4) bonds, with branches formed through α-(1→6) linkage. It is serves as an energy-giving food and is the most prevalent carbohydrate in the human diet. It is also used in various industries, including confectionery, adhesives, beverages, papers, pharmaceuticals, textiles and building materials by readily converted in physical and chemical form. Pure starch is insoluble in alcohol or cold water. It is a tasteless and odorless powder, that appeared like shiny white.

2. Isolation of starch from various sources of food

2.1 *Isolation of starch from cereals*

Blazek and Copeland [4] was extracted starch by using a two-step procedure from the wheat flour.

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The first step involved enzymatic removal of proteins and later extraction of free lipids with ethanol. They studied on amylose content, amylose chain length distribution and their correlation with swelling power and starch pasting properties of wheat flour. They found that the pasting properties and swelling behavior of starches are significantly influenced by the amylose content and the distribution of amylopectin chain lengths.

Lumdubwong and Seib [15] isolated starch from wet-milled rice flour using both the NaOH method and the protease digestion method. They recovered the 95% starch with only 0.5% protein contamination at pH 10.0 by digestion with 1.1% protease. They found that starch recovery using the protease method was 10% higher than with the NaOH method. They also perceived that starch isolated by protease digestion had lower consistency after pasting, lighter in appearance and was contained more lipids.

Fabian et al. [7] used defatted rice bran to extract starch. At first defatted rice bran was soaked in water, then blended and washed with alcohol, water, and an alkaline solution. The study aimed that the by-products of milling can be underused. The starch that was recovered was found to be 83% of the rice bran. They observed some of the properties of rice bran starch that also include retrogradation and gelatinization.

Singh et al. [25] analyzed the thermal and physicochemical properties of three rice types: Thailand rice (Indica), Nipponbare (Japonica), and Himenomochi (Japonica waxy) in their grain, flour, and starch forms. Indica rice was slender with the highest protein and amylose levels, while Japonica varieties were rounder and thicker. Waxy rice was the softest, cooked Indica rice was the hardest, and Japonica rice showed stickiness.

Defatted starches exhibited reduced glass transition temperatures (Tg), with similar Tg values for Indica and Japonica waxy starches. Indica had the highest melting point, and other properties like viscosities were also explored.
Suma and Urooj [27] extracted starch from pearl millet, employing a series of soaking, screening, and centrifugation steps for purification. They found the starch to be of high purity, with low non-starch components and amylose content. The starch was classified as non-waxy due to its fragility and disintegration at 65°C. Its low water and oil holding capacity was attributed to low protein and fiber content, though the waxy starch showed higher oil absorption due to its large surface area.
Wankhede et al. [31] studied pearl millet starch extraction, characterization and their digestion. The starch content was found to be 60.2% on a whole-grain basis, exhibiting two-stage swelling and moderate solubility patterns in an aqueous medium. The amylose content in millet starch was determined to be 22.8%, with a gelatinization temperature range of 69.5, 74.0, and 77.5°C. A viscoamylographic examination of an 8% (w/v) starch paste showed a peak viscosity, but holding it at 93°C for 30 minutes significantly reduced this peak viscosity. However, when cooled to 50°C, the viscosity of the starch paste increased sharply due to amylose retrogradation. Scanning electron microscopy was used to study the extent and modes of action of glucoamylase and human salivary α-amylase on the native starch granules.
Šubarić et al. [26] was isolated starch from oat and barley. The kernel of oat and barley was melted and then it was suspended at a ratio 1:2 (w/v) in distilled water. The adjusted pH was 11 with 1M NaOH. After the incubation was over, the filtration of slurry was done and the suspension of starch was left to rest for 30 minutes. Then it was decanted and followed by centrifugation. The removal of upper layer was done which is of grey color and then remaining starch was allowed to be suspended in distilled water then its neutralization with 1.0M HCl was done along with centrifugation. The obtained starch was then air-dried throughout the night. The resulting starch was then observed for properties like solubility, pasting properties, gelatinization, swelling power and retrogradation.
Hoover and Vasanthan [9] isolated starch from oat grains by soaking the grains in distilled water after mixing the mix was then allowed to pass through cheese cloth followed by centrifugation for 15 min at 5000g, the overlying liquid was discarded while the sediment was hanged in 0.2% NaOH. This process was replicated six times and the resultant sediment was suspended in distilled water after filtration it was neutralized to pH 7.0 with HCl, this HCl was removed by washing in distilled water and filter cake was obtained. It was found that the starch's yield was found to be 23.4% and scientist found some of its properties like total amylose content, size and shape. They studied on comparative characteristics of isolated wheat and oat starches.
Sandhu, Singh and Kaur [23] separated starches from popcorn, dent corn and baby corn and comparatively studied for rheological, physicochemical and morphological, thermal characteristics. They found that popcorn and dent corn differed significantly in various properties for different fractions 6.33 and 13.64 um was the range of granule diameter of the starch separated from different fractions. It was found that the starch granule can be from oval to polyhedral shape. The starch granule of baby corn was found to be oval while starch obtained from other corn type was found to be polyhedral. The range of amylose content for different corn types was found to be in 15.3% and 25.1%. It was found that swelling power, amylose content, solubility and mean granule diameter was lowest in baby corn starch.
Madhusudhan and Tharanathan [16] compared the physicochemical and digestibility properties of starches from rice and ragi (finger millet). Both starches showed single-stage swelling, low solubility in water, and high solubility in DMSO (100% for rice, 65% for ragi). Rice starch had higher digestibility, with C16:0 fatty acids, while ragi contained C16:0 and C18:2, and both had 22-30% amylose. Ragi starch had higher hot paste viscosity but lower setback viscosity than rice.
Tester and Morrison [28] studied swelling in cereal starches, finding it began at 45-50°C for wheat and led to gelatinization, dissociating crystalline clusters and causing loss of birefringence. Amylopectin controlled swelling, while amylose and lipids inhibited at above 60°C.

2.2 *Isolation of starch from tuber crops*

Julianti et al. [10] investigated the physicochemical and nutritional properties of cassava starch. As a raw material, cassava starch is low in protein, exhibits inconsistent viscosity and gel-forming ability, is not resistant to high temperatures, acidic conditions, or mechanical processing, and is prone to syneresis, making it unsuitable for industrial use. The primary objective of their research was to enhance the physical and chemical properties of the starch and improve its nutritional value compared to previous studies through various modification techniques. This modification was achieved through several fermentation processes, including natural fermentation (soaking in tap water for 16 days and in distilled water for 16 hours at 30°C) and lactic acid fermentation (soaking in a 1% lactic acid solution for 16 hours at 30°C). Scientists found that naturally fermented and under sun-dried based fermented starch showed better physicochemical and functional properties (water and oil absorption property, paste clarity, colour etc.).
Kundu et al. [13] extracted starch from various sources, including potato, maize, and cassava, using a sodium metabisulphite solution. The yield percentage of the isolated starch from these sources was satisfactory. They prepared pre-gelatinized starch and carboxymethylated derivatives of these starches, then assessed their pharmaceutical properties, such as solubility, pH, loss on drying (LOD), iron content, oxidizing substances, and microbial contamination. From their findings, they concluded that pre-gelatinization and carboxymethylation can be performed to achieve the desired level of utilization and that the extracted starches and their derivatives could serve as pharmaceutical excipients as well as for other commercial applications.
Moorthy et al. [18] extracted starch from sweet potato tubers and reviewed the rheological, thermal, functional and physicochemical properties of sweet potato starch and flour. They found wide variations in biochemical composition depending upon the origin of the tubers and processing conditions. They were observed that sweet potato starch has the highest starch content next to cassava among the tropical tuber crop and the extraction process is relatively easy compared to cereals.
Babu and Parimalavalli [2] isolated starch from sweet potato by using different agents which influence starch properties. They used Sodium metabisulphate, Sodium chloride and Distilled water methods for the isolation of starch and based on different isolation methods they compared and studied about the functional, chemical,

pasting and structural properties of starches and found that the yield of distilled water was highest (10.20% of starch recovery). Starches exhibited similar chemical properties but their swelling power and pasting properties changed due to different isolation methods. C-type diffraction pattern was observed in sweet potato starches. They also studied about the shape and size of isolated starch and noticed that granules were of small size i.e. 2.90 μm of distilled water extracted starch in SEM. It was discovered that ash, amylose and total starch content had high degree of positive correlations. In this research, they concluded that changes had been brought in the yield, pasting and structural properties of sweet potato starch by using different isolation methods.

Ríos-Ríos et al.[22] studied the physicochemical and nutritional properties of Taro coconut or Chinese taro (*Colocasia antiquorum*) starch which is grown in Oaxaca, Mexico. The shape of granules of coconut or Chinese taro starch was truncated ellipsoidal. They determined the physicochemical properties i.e. moisture, ash, protein, fat and fiber in a dry basis and also determined amylose and amylopectin contents and found amylopectin content was greater than amylose content. As the temperature increases solubility, swelling power, and water absorption capacity was found to be change. In this research the value of transmittance (0.3%) and apparent viscosity (100 to 150 cp) was determined in Taro starch. The nutritional characterization had was revealed that the starch content of coconut or Chinese taro was much more which was present in available form only 3% or less starch was found which could not be easily available. Coconut or Chinese taro is an unconventional source of starch that is grown in Oaxaca, Mexico, which in new product development.

More et al. [19] extracted starch from taro and enzymatically modified it with α-amylase, creating enzyme-treated starch (ETMS) and using unmodified starch (ES) as a control. They found that ETMS had lower amylose content, water absorption, and dispersibility but higher swelling power and enzyme digestibility than ES, while solubility remained unchanged. ETMS, particularly at 0.5%, was found to be the best stabilizer for ice cream, enhancing foam stability, viscosity, and overrun. The study concluded that α-amylase-modified taro starch is effective as a stabilizer in ice cream production.

Mweta et al. [20] compared starches from Malawian cocoyams to cassava and corn starches. Cocoyam starches had smaller granules, and lower calcium, but higher potassium and phosphorus levels. They exhibited lower reducing capacity, higher iodine absorption, and varied in acid hydrolysis. Cocoyam amylopectin had higher molecular weight, with greater solubility, gelatinization temperatures, and retrogradation tendencies than cassava and corn starches. However, cocoyam starches had lower water absorption, swelling power, paste clarity, and viscosity. The study concluded that cocoyam starches showed distinct physicochemical variations compared to cassava and corn starches.

Otegbayo, Oguniyan and Akinwumi [21] analyzed 45 categories of yam (Dioscorea species) to study their physicochemical and functional properties. They found that *D. cayenensis*, *D. rotundata*, *D. alata*, and *D. bulbifera* had large starch granules, while *D. dumetorum* had smaller ones. Granules were mostly triangular, oval, or round. Gelation concentration ranged from 4-16%, and paste clarity decreased with storage. The starches showed high syneresis and varied pasting characteristics, with *D. bulbifera* having the highest viscosity. Yam starches demonstrated significant differences in properties, making them useful for both food and non-food applications.

Umerie,Obi and Okafor [30] extracted 20.51% yield of starch from the tubers of Cyperus esculentus and studied various properties, including granule size, cold water extractives, moisture and ash contents, paste stability, clarity, adhesive strength, and line-spread at 50°C. They compared the granule sizes of the tuber starch to those of rice starch, noting that the cold water extractives, moisture, and ash contents aligned with standard values for starches. The experimental results indicated that the paste stability, clarity, and adhesive strength were satisfactory, and the line-spread test results suggested its potential use in animal feeds and confectionery products.

2.3 *Isolation of starch from fruits & vegetables and other sources of plants*

Hassan et al. [8] extracted starches from four diversities of mango seed *(Mangifera indica)*. The characterization had been done by using the conventional method for industrial application. The result showed a significant difference in the starch content amongst the varieties. They studied the physicochemical properties like ash content, moisture content, starch lipid and starch protein of the seed & they were found low. They also examined the functional properties of the seeds, including swelling power, solubility, and amylose content, and found that these properties showed little variation among the different varieties. In contrast, the amylopectin content exhibited significant variation across the varieties. The onset gelatinization temperature of the starches ranged from 60.5 to 63.4°C, while the conclusion gelatinization temperature ranged from 70.2 to 73.4°C.

Correia, Nunes and Beirao-da-Costa [6] used two acorn fruits to isolate starch by using methods like enzymatic and alkaline for study of its physical and chemical properties. The method that was used for isolated caused changes in properties like syneresis, thermal resistant starch content pasting and rheological properties of isolated starch. The syneresis value along with turbidity was found to be low at ambient temperature, but an increment in the value of synresis takes place at freezing temperature. Finally it was concluded that raw structure of starches greatly affected by the enzymatic isolation procedure because this method presented less interesting function properties.

Maniglia and Blácido [17] isolated starch by soaking babassu mesocarp in water and as well as alkaline. Though it is rich in starch but it is only used as animal food and biomass. Isolated starch by soaking in the alkaline method provided large yield (85%) pure starch (99%) than water soaking method, however larger loss of total phenolic compound taken place in the alkaline method. Compared with the water soaking method the alkaline starch contained agglomerated starch granules with polymodal particle size distribution, effective solubility and superior swelling power. Alkaline Soaking starch has larger thermal stability property and crystallinity properties due to its more amylopectin content and less amylose content. The starches isolated from babassu mesocarp which were yellowish or reddish in colour could be applied as bioactive film or as food ingredients because of the presence of phenolic compounds as well as its antioxidant activity.

Bello-Pérez et al. [3] studied starch from pinhão seeds (*Araucaria angustifolia*), which made up 34% of the seeds and contained low levels of phenolics, proteins, and lipids. Pinhão starch had small, round granules and was white, odorless, and stable, making it suitable for the food industry. Compared to corn starch, pinhão starch had lower gelatinization enthalpy and temperature, less amylose (25%), and less retrogradation.

Its high solubility, swelling, and storage properties make it useful for glucose and fructose syrup production. The easy extraction process and high yield make pinhão starch commercially viable.

Toledo, Azzini and Reyes [29] were separated starch from bamboo culm in 8.5% yield. They studied on different properties of the starch. They characterized the starch granules as polygonal in shape, ranging in size from 1 to 12 µm, and found an amylose content of 24%. The experimental data indicated that the granules were compact, with a density of 1.531 g/cm^3, which likely contributed to their low swelling power and solubility in water, as well as poor solubility in dimethyl sulfoxide (DMSO). The initial pasting temperature of the starch, determined using a Brabender amylogram, was 75°C, and it demonstrated a high susceptibility to breakdown under thermal and mechanical shear.

Kumar [12] conducted experiments with *Amaranthus hypochondriacus* (Annapurna), *Amaranthus hypochondriacus* (Durga), and *Amaranthus paniculatus* (Rajgeera) to achieve maximum starch recovery with improved color and minimal impurities. Through various experiments, they standardized the process by adjusting the particle size of the flour (using grain grits, 30 mesh, and 60 mesh), the concentration of alkali (NaOH) (ranging from 0.05% to 0.30% w/v), and the mesh size of filter screens (70, 100, 200, and 300 mesh). Other process variables, such as the volume of alkali used, steeping time (24 hours), steeping temperature (4°C), and centrifuge speed (3000g for 20 minutes), were kept constant. They found that the highest starch recovery was achieved with *Amaranthus hypochondriacus* (Durga) at 34.35%, accompanied by minimal protein content (0.36%), fat content (0.30%), ash content (0.67%), and fiber content (0.26%) while the *Amaranthus paniculates* was highest in starch yields (37%) but with higher protein fraction (1.04) therefore *Amaranthus hypochondricus* (Durga) line was selected as best among above experimented.

3. Improvement in the properties of starch using different methods

3.1 *Fermentation method*

In this method, the properties of wheat starch are enhanced through a natural fermentation process involving soaking, crushing, and drying the wheat grains, known as Seera. This traditional fermented food is popular in Himachal Pradesh, India, and offers numerous health benefits. Additionally, it significantly improves flavor, nutritional value, and storage stability, while also reducing cooking time.

Ahmad, Nema and Bashir [1] prepared *Seera* at the commercial level by applying different drying technique. This research aimed to produce Seera on a large scale with enhanced qualities. Various physicochemical properties, including rheological properties, oil absorption capacity, bulk density, and the contents of moisture, fat, protein, and carbohydrates, were examined to improve its safety and nutritional value. A comparative analysis of the physicochemical properties of Seera produced using different drying techniques was also conducted. Rheological studies indicated that the Herschel–Bulkley model was the best fit, demonstrating shear-thinning behavior that highlighted the elastic properties and suitability for high-shear applications. The experimental results showed that water absorption capacity increased compared to wheat flour, with the highest absorption observed in freeze-dried Seera, followed by oven-dried and sun-dried samples. Conversely, oil absorption capacity decreased relative to wheat flour, with the lowest values recorded for freeze-dried Seera. Carbohydrate content and bulk density increased significantly in the Seera samples, while fat, protein, and moisture content decreased markedly. Additionally, the transition temperatures changed significantly for the Seera samples, while the gelatinization and Fourier transform infrared patterns remained unchanged with drying.

In another study, Savitri et al. [24] studied various microbiological and biochemical parameters during the fermentation of wheat flour (*Seera*). The microbiological study revealed that Seera primarily contained yeasts such as *Saccharomyces cerevisiae, Cryptococcus laurentii*, and *Torulospora delbrueckii*. Among the bacteria isolated were *Lactobacillus amylovorus, Cellulomonas sp., Staphylococcus sciuri, Weisella cibaria, Bacillus sp., Leuconostoc sp.*, and *Enterobacter sakazakii*. The biochemical study described protein content decreased from day first to fifth day of fermentation and total sugars decreased with the time of fermentation, whereas starch content decreased initially on dry weight basis from first to fourth day but after steeping and drying of *Seera*, the starch content increased on dry weight basis. They found that with the fermentation up to fourth day amylase and protease activity increased then it started decreasing and very low amylase activity was recorded in the final product. Along with the fermentation of *Seera* significant increase was observed in proteins mainly thiamin, riboflavin, nicotinic acid and cyanocobalamin and also a significant increase in the amount of essential amino acids especially methionine, phenylalanine, and threonine, lysine and leucine were observed.

3.2 *Microfluidization method*

Microfluidization is a type of high-pressure homogenization, which creates fine emulsion [11]. It works on the principle that fluid is forced into the interaction chamber at very high pressure with high velocity, where the fluid is divided into two streams and collides at 180° in the interaction chamber. Due to the rapid drop in pressure and impact, cavitation, shear, and turbulence effects occur, resulting in emulsification [5].

Liu, Chien, and Kuo [14] studied the effect of ultra-high pressure homogenization or microfluidization on soybean flour and tofu production. They observed that the size of the soy flour particles decreased due to the treatment. They created two suspensions with 15% and 20% soy flour concentrations and treated them at four different pressures and cycles using UHPH. The suspension of soy flour treated by UHPH had comparatively smaller and more consistent particle sizes than the control. The tofu made from the 20% soy flour suspension, treated by UHPH at a pressure of 150 MPa for 3 cycles, had the lowest expressible water and syneresis. Tofu produced by UHPH was found to have high levels of functional components, such as fiber, due to its continuous honeycomb structure and regularity.

Che et al. [5] examined the effect of ultra-high pressure homogenization or microfluidization on cassava starch. They used a high-pressure homogenizer to homogenize a suspension of cassava starch at various pressures. It was found that partial gelatinization of cassava starch occurred after homogenization at high pressure. As the pressure of homogenization increased, the degree of gelatinization also increased. The measurements taken through laser scattering showed that there was an increase in the particle size when homogenized at 100 MPa as the granules swelled. It was also found that high-pressure homogenization did not affect the crystalline structure of starch granules, which was confirmed by the X-ray diffraction pattern that showed no changes after homogenization [5].

4. Conclusions

Many researchers extracted the starch from a variety of foods by different methods and studied the advancement in the properties of starch such as pasting property, paste clarity, solubility and morphology of starch. Different isolation methods have various effects on the advancement of starch property. This study also concluded the improvement of starch property due to the fermentation process in the nutritional and functional property of fermented starch such as digestibility paste clarity, water absorption capacity and solubility. Microfluidization also enhanced the functional property of starches by applying high pressure which may use in the new product development.

Future Scope of Study

Future research could focus on optimizing the isolation and modification processes for starches from a wider variety of food sources to improve yield and purity. The application of novel techniques, such as enzymatic treatments and nano-technology, for enhancing the functional properties of starch could provide new avenues for food product development. Additionally, the sustainability of these processes, especially in terms of energy consumption and waste reduction, will be crucial for long-term industrial applications.

Declaration of conflict of interest

The authors declare no conflict of interest related to this study.

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References

1. Ahmad, S., Nema, P. K., and Bashir, K. 2017. Effect of different drying techniques on physicochemical, thermal, and functional properties of Seera. Drying Technology 36 (11): 1284–1291.

2. Babu, A. S., and Parimalvali, R. 2014. Effect of starch isolation method on properties of sweet potato starch. The Annals of the University Dunarea De Jos of Galati. Fascicle VI - Food Technology 38 (1): 48–63.

3. Bello-Pérez, L. A., García-Suárez, F. J., Méndez-Montealvo, G., Nascimento, J. R. O., Lajolo, F. M., and Cordenunsi, B. R. 2006. Isolation and characterization of starch from seeds of Araucaria brasiliensis: A novel starch for application in food industry. Starch 58 (6): 283–291.

4. Blazek, J., and Copeland, L. 2008. Pasting and swelling properties of wheat flour and starch in relation to amylose content. Carbohydrate Polymers 71: 380–387.

5. Che, L. L., Wang, D., Ozkan, L., Chen, N. D., and Zhihuai, X. M. 2007. Effect of high-pressure homogenization on the structure of cassava starch. International Journal of Food Properties 10: 911–922.

6. Correia, P. R., Nunes, M. C., and Beirao-da-Costa, M. L. 2013. The effect of starch isolation method on physical and functional properties of Portuguese nuts starches. I. Chestnuts (Castanea sativa Mill. var. Martainha and Longal) fruits. Food Hydrocolloids 27: 256–263.

7. Fabian, C., Ayucitra, A., Ismadji, S., and Ju, Y. H. 2011. Isolation and characterization of starch from defatted rice bran. Journal of the Taiwan Institute of Chemical Engineers 4: 86–91.

8. Hassan, L. G., Muhammad, A. B., Aliyu, R. U., Idris, Z. M., Izuagie, T., Umar, K. J., and Sani, N. A. 2013. Extraction and characterization of starches from four varieties of Mangifera indica seeds. Journal of Applied Chemistry 3 (6): 16–23.

9. Hoover, R., and Vasanthan, T. 1992. Studies on isolation and characterization of starch from oat (Avena nuda) grains. Carbohydrate Polymers 19 (4): 285–297.

10. Julianti, E., Lubis, Z., Ridwansyah, E. Y., and Suhaidi, I. 2011. Physicochemical and functional properties of fermented starch from four cassava varieties. Asian Journal of Agricultural Research 5: 292–299.

11. Kumar, A., Badgujar, P. C., Mishra, V., Sehrawat, R., Babar, O. A., and Upadhyay, A. 2019. Effect of microfluidization on cholesterol, thermal properties, and protein digestibility (in-vitro and in-vivo) of milk. LWT-Food Science and Technology 116: Article 108523.

12. Kumar, N., Chauhan, A., Singh, S., and Rana, J. C. 2013. Process standardization for extraction of starch from amaranth cultivars. International Journal of Biotechnology and Bioengineering Research 4: 617–626.

13. Kundu, S., Muslim, T., Rahman, M. A., and Faisal, M. A. A. 2011. Extraction of starch from different sources: Their modification and evaluation of properties as pharmaceutical excipient. The Dhaka University Journal of Science 59 (2): 263–266.

14. Liu, H., Chien, J. T., and Kuo, M. 2013. Ultra high pressure homogenized soy flour for tofu making. Food Hydrocolloids 32: 278–285.

15. Lumdubwong, N., and Seib, P. A. 2000. Rice starch isolation by alkaline protease digestion of wet-milled rice flour. Journal of Cereal Science 31: 63–74.

16. Madhusudhan, B., and Tharanathan, R. N. 1995. Legume and cereal starches—why differences in digestibility? Part II. Isolation and characterization of starches from rice (O. sativa) and ragi (finger millet, E. coracana). Carbohydrate Polymers 28 (2): 153–158.

17. Maniglia, B. C., and Tapia-Blacido, D. R. 2016. Isolation and characterization of starch from babassu mesocarp. Food Hydrocolloids 55: 47–55.

18. Moorthy, S. N., Sanjeev, M. S., and Shanavas, S. 2012. Sweet Potato Starch: Physico-chemical, functional, thermal, and rheological characteristics. Fruit, Vegetable and Cereal Science and Biotechnology 6 (1): 124–133.

19. More, P. R., Solunke, R. V., Talib, M. I., and Parate, V. R. 2017. Stabilization of ice-cream by incorporating α-amylase modified taro (Colocasia esculenta) starch. International Journal of Creative Research Thoughts 1–7.

20. Mweta, D. E., Labuschagne, M. T., Bonnet, S., Swarts, J., and Saka, J. D. K. 2010. Isolation and physicochemical characterisation of starch from cocoyam (Colocasia esculenta) grown in Malawi. Journal of the Science of Food and Agriculture 90 (11): 1886–1896.

21. Otegbayo, B., Oguniyan, D., and Akinwumi, O. 2014. Physicochemical and functional characterization of yam starch for potential industrial applications. Starch 65: 235–250.

22. Ríos-Ríos, K., González-Mondragón, E., Segura-Campos, M., Ramírez-Jiménez, M., López-Luna, J., López-Martínez, I., and Betancur-Ancona, D. 2016. Physicochemical and nutritional characterization of starch isolated from Colocasia antiquorum cultivated in Oaxaca, Mexico. Journal of Chemistry 2016: Article 6721418, 1–7.

23. Sandhu, K. S., Singh, N., and Kaur, M. 2004. Characteristics of the different corn types and their grain fractions: Physicochemical, thermal, morphological, and rheological properties of starches. Journal of Food Engineering 64 (1): 119–127.

24. Savitri, N., Thakur, D., Kumar, D., and Bhalla, T. C. 2012. Microbiological and biochemical characterization of Seera: A traditional fermented food of Himachal Pradesh. International Journal of Food And Fermentation Technology 2 (1): 49–56.

25. Singh, V., Okadome, H., Toyoshima, H., Isobe, S., and Ohtsubo, K. 2000. Thermal and physicochemical properties of rice grain, flour, and starch. Journal of Agricultural and Food Chemistry 48 (7): 2639–2647.

26. Šubarić, D., Babić, J., Lalić, A., Ačkar, D., and Kopjar, M. 2011. Isolation and characterisation of starch from different barley and oat varieties. Czech Journal of Food Science 29 (4): 354–360.

27. Suma, P. F., and Urooj, A. 2015. Isolation and characterization of starch from pearl millet (Pennisetum typhoidium) flours. International Journal of Food Properties 18 (12): 2675–2687.

28. Tester, R. F., and Morrison, W. R. 1990. Swelling and gelatinization of cereal starches. I. Effects of amylopectin, amylose, and lipids. Cereal Chemistry 67 (6): 551–557.

29. Toledo, M. C. F., Azzini, A., and Reyes, F. G. R. 1987. Isolation and characterization of starch from bamboo (Guadua flabellata). Starch 39 (5): 158–160.

30. Umerie, S. C., Obi, N. A. N., and Okafor, E. O. 1997. Isolation and characterization of starch from Cyperus esculentus tubers. Bioresource Technology 62 (1): 63–65.

31. Wankhede, D. B., Rathi, S. S., Gunjal, B. B., Patil, H. B., Walde, S. G., Rodge, A. B., and Sawate, A. R. 1990. Studies on isolation and characterization of starch from pearl millet (Pennisetum americanum (L.) Leeke) grains. Carbohydrate Polymers 13 (1): 17–28.