Chapter

Potato Starch as Affected by Varieties, Storage Treatments and Conditions of Tubers

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Abstract

Potato is among the widely grown crop of the world. It is likely that a large portion of the crop is consumed fresh but majority of it is processed into various products, starch being the predominant one. Starch can greatly contribute to the textural properties of many foods and is widely used in food industry as raw material. Since raw potatoes are perishable and accessible only for few months of the year, the food and starch industry has to rely on stored potatoes during off-season. The various varieties of the crop available in the region, storage conditions, pre and post-storage treatments given to the tubers, packaging materials used, etc. are influencing the physical, chemical and functional characteristics of starch extracted from it. The extraction technology from tubers is also having a significant effect on the quality of starch. The knowledge of physical, chemical and functional characteristics of potato starch as affected by varieties, storage treatments and conditions of tubers will help in ensuring uniform and desirable quality of starch for food industry and also provide information for breeding programs and developing the proper postharvest management practices of potatoes.

Keywords: curing, extraction methods, functional properties, packaging potato starch, sprout suppressants, storage conditions, varieties

1. Introduction

Potato (*Solanum tuberosum* L.) is the most important food crop in the world after wheat, rice, and maize. UNESCO (United Nations Educational, Scientific and Cultural Organization) declared potato as the food of the future during the 'International Year of Potato 2008' and stated potato as the third most important world food crop. Potato production increased significantly in India during the last six decades and it became the second-largest producer of potatoes after China [1]. Potatoes contain 70–80% water, 16–24% starch (85–87% dry mass), and trace amounts of proteins and lipids [2].

Potatoes are a perishable crop, and due to insufficient, expensive, and widely dispersed refrigerated storage facilities, there are frequent instances of market over-supply, resulting in significant economic damage to farmers and agricultural wastage.

Various storage treatments and technologies have been proposed to extend the shelf life of potato tubers. Because raw potatoes are accessible only for few months of the year, the food and starch industry has to rely on stored potatoes during off-season. A proper storage climate helps keep potatoes in excellent condition by avoiding excessive weight loss, microbial spoilage, sprout development, and quality degradation. Potatoes are often stored in long-term postharvest cold storage (8–12°C, 85–90% RH) to retard physiological processes and extend shelf life. Maintaining low temperatures during the storage time is dependent on the tubers' intended usage

Prolonged storage of potatoes requires sprout inhibition either by use of irradiation or sprout inhibitor chlorpropham (CIPC, isopropyl 3-chlorocarbanilate) treatment [3, 4] or the usage of heat treatment [5]. The CIPC alternatives for sprout inhibition are maleic hydrazide (MH), 1,4-Dimethylnaphthalene, and ethylene [6]. Heat treatment, essential oils of some herbs and spices—also effectively reduce sprouting and can be applied to organically grown potatoes [7, 8]. The sprout inhibiting treatments besides affecting the physiology of tubers also alter the properties of starch [9].

Starch plays a major role in the sensory characteristics of a wide variety of foods and is extensively used in agro-industrial applications as a thickener, colloidal stabilizer, gelling agent, bulking agent, and water retention agent. Because of the higher granule size and purity of potato starch, as well as the amylose and amylopectin chain lengths and the presence of phosphate ester groups on amylopectin, it stands apart from other cereal starches (corn, wheat, rice, etc.). Potato starch is an excellent texture stabiliser and regulator in food production systems.

The adaptability of starch in a wide range of food items makes it a hot topic among researchers studying carbohydrate polymers. As the genetic basis of the starch changes, so do its physicochemical attributes and functional features, as well as how unique they are in different foods and drinks [10]. Even within the same botanical species, cultivars of the same plant grown in different environments and cultural settings have vastly different starch structures and functions. This diversity results in a wide variety of starches with varying cooking, textural, and rheological characteristics that are linked to their physicochemical, morphological, and thermal properties. The following sections of the chapter deal with the starch characteristics as influenced by extraction methods, cultivars, curing, sprout inhibitors and storage conditions of potato tubers.

2. Effect of extraction methods

Depending on the plant source and intended application for the starch, several techniques can be used to extract it. Different researchers have utilized a variety of extraction methods to separate starch, including steeping periods, extraction temperatures, chemical concentrations and nature, enzymes, and so on. The chemical composition and physical characteristics of starch are both influenced by the extraction processes. To procure a pure product with maximum yield and recovery, lowest cost, and application of a series of interrelated stages allowing the non-starchy fraction to be removed without affecting the granule native structure and minimal incidence on its physico-chemical and mechanical properties, selecting an appropriate starch extraction method is desirable.

The chemical and physical characteristics of starch are altered throughout the extraction process. According to Neeraj *et al.* [11], water temperature affected potato tuber starch extraction. Extraction temperatures of 30°C and 60°C produced improved starch yields, water absorption capacity (WAC), and whiteness. The use of 0.25% NaOH for chemical extraction increased WAC while decreasing ash content. The combination of sodium dodecyl sulphate (SDS) and mercaptoethanol (ME) to remove lipids increased amylose and starch purity while reducing amylopectin, moisture, and fat. Whiteness values were greater in the extraction employing NaOCl bleaching agent, while starch yields were higher in the enzymatic extraction by cellulose. The combination treatment of NaOH, SDS-ME, Na-hypochlorite and cellulase produced significantly higher starch yield and WAC than the simple cold water extraction method. It also resulted in significantly higher swelling power and solubility, light transmittance and whiteness, as well as trough and final viscosity of the extracted starch.

The different extraction techniques resulted in varying proportions of tiny and big starch granules. The Na-bisulphite treatment had the highest percentage of small-sized particles, whereas the other methods had no noticeable variations in particle size. Intact starch granules with smooth surfaces were found in the water-treated starch, but granules of starch treated with Na-bisulphite or propanol-water had somewhat rough and pitted surfaces, as well as fractures inside the granules (**Figure 1**) [11]. Lin *et al*. [12] reported that alcohol treatment caused not only the disappearance of 'Maltese cross' pattern in the center of granule but also the occurrence of cracks inside the granule. Betancur *et al.* [13] observed that Na-bisulphite treatment resulted in acid hydrolysis, with the hydroxonium ion attacking the glycosidic oxygen atom and hydrolyzing the glycosidic linkage, altering the physicochemical properties of starch and causing the formation of some cracks on the starch surface.

Phosphorus is present as phosphate monoesters and phospholipids in potato starches [14]. Phosphorus alters the functional characteristics of starches, which is significant both technologically and nutritionally. The phosphate monoesters are covalently linked to the starch's amylopectin portion. The majority of the phosphate groups are covalently linked to the amylopectin fraction at the C-6 (70%) and C-3 (30%) locations of the glucose units. It has been demonstrated that the phosphate concentration of starches has an effect on their physicochemical qualities and end applications, including starch pasting capabilities, gel strength and clarity, stickiness and viscosity [15]. Neeraj *et al*. [11] reported that starch extracted by water had higher, while extracted by Na-hypochlorite lower phosphorus content. The decrease in phosphorus content by Na-hypochlorite (NaOCl) was attributed to acid hydrolysis of amylose and amylopectin chains, reducing the ash content of starch and hence its mineral content. NaOCl may have caused oxidative degradation of amylopectin and amylose chain and thereby reducing the phosphorus content [16].

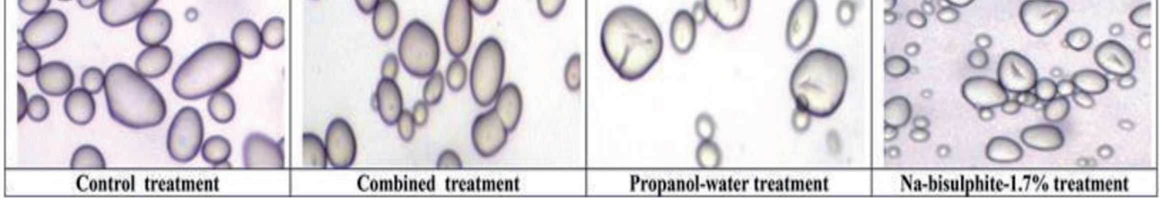

Figure 1.
Effect of various methods of extraction on potato starch granule (source: [11]).

The variations in WAC between different starches are attributable to the degree to which water binding sites are available in their granules. The hydroxyl groups and inter-glucose oxygen atoms are thought to be the binding sites. The capacity of these starches to interact with water is determined by their ultrastructural (molecular arrangement, amorphous and crystalline regions) and compositional variations (primarily amylose and amylopectin). The capacity of commercial starches to bind water is critical to the quality and texture of some food items because it protects them from effects such as syneresis, which can occur during retorting or freezing [15]. It has been reported that different extraction techniques significantly affected WAC of potato starch. The alkali treatment with NaOH resulted in a greater WAC, but the NaOCl extraction technique resulted in a lower WAC [11, 17]. The increased WAC in alkali treated starch might be due to ions (Na^+) diffusing into the amylose-rich amorphous areas of the granules, destroying intermolecular interactions, altering the starch's crystalline structure, and leading the granules to absorb more water [18, 19]. Fat and protein that are located on the surface of starch granules are crucial for maintaining its structural stability [20]. Additionally, their presence has been demonstrated to significantly slow the rate of starch retrogradation [21]. Lipids have also been observed to form complexes with amylopectin's outer branches, therefore inhibiting starch retrogradation. It has been reported by Neeraj *et al* [11] that different extraction techniques have an effect on the protein and fat content of potato starch. The combined treatment of NaOH, SDS-ME, Na-hypochlorite and cellulose resulted in low protein content, but the cold water extracted potato starch had high protein content. The decreased protein content seen in combination treatment may be a result of the alkali, SDS, and protease present. Because NaOH is an excellent solvent and can solubilize the main protein enclosing the starch, alkaline steeping technique softens the protein-starch matrix, resulting in a starch deficient in protein and lipids [22]. SDS treatment was also found to be effective in removing the protein and lipids from the surface of starch granules [20].

Different extraction treatments resulted in significant variations in swelling power and solubility index of the extracted starch. Neeraj *et al*. [11] reported that the swelling power and solubility were maximum for starch extracted by NaOH, while it was minimum in Na-bisulphite. Wang and Wang [23] reported that NaOH treatment caused the removal of protein and lipids from the surface of the starch granules and then allowed the starch granules to swell more and open up the small pores or crevices on the granule surface. Sajeev and Moorthy [24] reported that reduced swelling power of sulphite-treated starches may be owing to the fact that sulphite interacts stoichiometrically with oxygen (2 moles of sulphite to 1 mole of oxygen), forming sulphite free radicals and the superoxide ion ($^{\cdot}O^{2}$-).

The freeze-thaw stability (syneresis) of starch is a helpful indication of its retrograde tendency. Syneresis is a critical characteristic that is used to determine a starch's capacity to survive unfavourable physical changes that occur during freezing and thawing. Extraction procedures also have a major influence on syneresis. Neeraj *et al* [17] reported that the maximum synerisis was observed in potato starch extracted by Na-bisulphite and minimum in starch extracted by combined treatment of NaOH, SDS-ME, Na-hypochlorite and cellulose. The enhanced syneresis induced by starch following Na-bisulphite treatment may be attributed to the acid-thinning process increasing the fraction of linear chain starch in the sample, which enhanced the inclination to retrograde.

Granule swelling, granule remnants, leached amylose and amylopectin, as well as the molecular weights and chain lengths of amylose and amylopectin, have all been reported to vary with granule size, resulting in the development of turbidity and reduced light transmittance in refrigerated starch pastes [25]. It has been reported by Neeraj *et al.* [11] that the potato starch extracted by Na-hypochlorite treatment showed higher transmittance than native starch because the oxidized starch had a lower tendency for molecular re-association. The presence of hydrophilic functional groups in oxidised starches, particularly carboxyl groups, may account for the increased transmittance. It can also be ascribed to the chemical replacement of carbonyl and carboxyl functional groups for the hydroxyl groups in starch molecules, leading to repulsion between neighbouring starch molecules and decreased inter-chain interaction, allowing for increased transmittance [26].

3. Effect of potato varieties on starch

Tuber starches from different potato breeds vary in terms of crystallinity, granule shape, and other physical and chemical characteristics. The reactivity of the starches in various potato genotypes varied significantly [27]. The accumulation of starch in potatoes is genotype- and environment-dependent, as well as genotype-environment interaction dependent [28]. Due to the variations in tuber development rates amongst cultivars, the harvest dates and hence the dry mater accumulation varied for different potato cultivars. Early maturing cultivars showed lower dry matter content and a lower starch content than late maturing types. Kufri Chipsona-4 produced the most, followed by Kufri Badshah, Kufri Sindhuri, and Kufri Bahar; and Kufri Pushkar produced the least amount of starch. Since Kufri Chipsona-4 is a medium to late maturing variety, it produced more starch than other cultivars [11].

Kaur *et al.* [29] screened 21 different potato varieties and reported lowest amylose content of 15.0% for Kufri Ashoka (Patna) and the highest of 23.1% for Kufri Badshah (Jalandhar) starch. Singh *et al.* [30] compared the starch amylose content among the potato varieties and reported that Kufri Jyoti starch had the highest amylose content, whereas Kufri Sindhuri starch had the lowest. The variations in amylose concentration across types of starch granules have been attributed to the activity of enzymes involved in the production of linear and branching components inside the starch granules during plant development [11].

Singh and Singh [31] reported that Kufri Badshah (KB) and Kufri Jyoti (KJ) starch paste showed higher light transmittance and lower turbidity values than Kufri Pukhraj (KP) potato starch pastes. Kaur *et al.* [32] observed that starches separated from varieties KJ and KB had lower transition temperatures (To; Tp and Tc), peak height indices (PHI), higher gelatinization temperature range (R) and enthalpies of gelatinization (ΔHgel) than KP. The swelling power, solubility, amylose content, and transmittance values of KJ and KB potato starches were found to be greater, whereas turbidity values were found to be lower. KP starch showed the highest WAC, while it was lowest for KJ starch, which can be attributed to the variation in granular structure and loose association of amylose and amylopectin molecules. Singh and Kaur [33] reported that large-size fractions from Kufri Sutlej (KS) and Kufri Jyoti (KJ) starch showed the highest retrogradation, while the same fraction from Kufri Chandermukhi (KC) starch showed the lowest retrogradation.

The water absorption capacity (WAC) has been reported to be different for the starches extracted from different varieties. Singh and Kaur [33] reported that Kufri Chandermukhi small granule fraction showed the highest WAC as compared to Kufri Sindhuri and Kufri Jyoti. Kaur *et al.* [29] observed that pasting temperature (PT) of different potato starches ranged from 64.5 to 69.5°C, the highest for Kufri Sindhuri and the lowest for Kufri Bahar. Neeraj *et al.* [11] maximum WAC in Kufri Chipsona-4 followed by Kufri Sindhuri, while it was minimum in Kufri Badshah. Differences in WAC across cultivars may be related to their starch's amylose and amylopectin levels. Additionally, it can be ascribed to granular structural variation. The presence of a significant number of phosphate groups on the amylopectin molecule may help explain the variations in WAC between starches isolated from various potato types [34].

The phosphorous content of extracted starch was found to be different for different potato varieties. It was minimum in Kufri Pushkar followed by Kufri Sindhuri, while it was maximum in Kufri Chipsona-4 [11, 17]. Pineda-Gomez *et al.* [35] studied the starch of potato cultivars growing in the Andean region in the south of Colombia. It was observed that the apparent amylose and phosphorus concentrations of starches extracted from Mambera, Ratona, and Pastusa cultivars of potato were much greater than those recovered from Unica and Roja-huila. Kaur *et al* [29] reported that the phosphorus content of starch granules is positively linked with the phospholipid concentration. Phospholipids are often abundant in phosphorus-rich starch granules, either adhering to their surface or enclosed within.

There were marked differences in swelling power (SP) of extracted starch from different potato varieties. It was maximum in Kufri Chipsona-4 followed by Kufri Bahar, while it was minimum in Kufri Badshah [11, 17]. Additionally, it was observed that Kufri Chipsona-4 included the least amylose and the most phosphorus, indicating a greater swelling power; however, Kufri Badshah contained the most amylose and the least phosphorus, indicating a lesser swelling power. The difference in SP between starches from various potato cultivars indicates that the affective bonding forces between granules are stronger in certain. The swelling ability of starch is directly proportional to its amylopectin concentration, since amylose functions as a diluent and swelling inhibitor.

Starches' swelling ability and solubility are strongly linked. Neeraj *et al.* [11] reported that maximum solubility was for the starch extracted from Kufri Chipsona-4 followed by Kufri Pushkar, while it was minimum in Kufri Badshah. The variations in swelling power and solubility of the starches among different varieties can be attributed to the differences in granule size, amylose content, molecular structure of amylopectin and the crystallinity as well as the granule organization.

Neeraj *et al.* [11] observed maximum light transmittance in starch extracted from Kufri Chipsona-4 followed by Kufri Bahar, while it was minimum in Kufri Pushkar. Higher transmittance led to greater starch paste clarity. The clarity of the paste varied significantly depending on the starch source, amylose/amylopectin ratio, chemical or enzymatic changes, and solute inclusion. Potato cultivars with a substantial increase in transmittance may be used in the jelly, beverage, and fruit paste sectors to get the appropriate consistency.

Syneresis, or freeze-thaw stability, is a critical characteristic used to assess a starch's capacity to survive the undesired physical changes that occur during freezing and thawing. Syneresis was discovered to be least in starch extracted from Kufri Pushkar, followed by Kufri Bahar, and to be most in Kufri Chipsona-4 [11, 17].

Kaur *et al.* [32] reported that endothermic peaks for several potato cultivars ranged from 59.96 to 68.89°C, the peak temperature was 63.37–64.58°C, and the final temperature was 67.4–68.9°C.

4. Effect of curing treatment of tubers

Freshly harvested potatoes have very short shelf life due to thin skin. Curing is accomplished by holding potatoes in dark at ~22°C and RH 90% for 10—15 days. During curing potatoes utilize the reserved food material to provide energy and metabolites to heal bruises and cracks and to develop periderm layer making the peel thick and impermeable to water. The various changes taking place in the characteristics of extracted starch from different varieties of potato due to curing of tubers was studied in detail by Neeraj *et al* [11]. It was reported that curing of tubers resulted in decreased starch yield, amylose content, swelling power, and solubility; but increased phosphorus content, WAC, and light transmittance of the extracted starch. The lower starch content in cured potatoes compared to fresh potatoes may be due to its utilisation in the process of periderm layer formation [36]. Van Der Maarel *et al.* [37] reported a decrease in amylose content in cured potatoes as a result of increased activity of the debranching enzyme glucoamylase, which breaks the -1,6 glycosidic bonds present in amylose to form linear amylose. The amylase, pullulanase, glucoamylase, and isoamylase further breakdown amylose into sugars. The increased phosphorus concentration in cured tubers might be attributed to the poor starch recovery from cured tubers that resulted in a greater phosphorus content per unit of recovered starch. The greater WAC content of cured potato starch can be attributed to its reduced amylose and higher phosphorus content. Liu *et al.* [38] found a negative connection between WAC and amylose and a positive correlation between WAC and phosphorus in starches. Reduced swelling power, solubility, and light transmittance of cured potato starch were attributed to its decreased amylose and high phosphorus concentrations.

Curing did not significantly affect the size of the starch particles and syneresis [39]. The syneresis exhibited a significant positive correlation with amylose content. Though the amylose content was slightly reduced by curing, still the syneresis was not affected [11, 17]. This might be because the amount of the change in amylose concentration was too little to have a meaningful influence on syneresis, or because other variables such as crude fibre, fat, protein, and granular structure also playing a role in syneresis [18].

5. Effect of sprout inhibiting treatments

The sprout inhibiting treatments besides affecting the physiology of tubers also alter the properties of various biochemical constituents. CIPC, also referred as chlorpropham is the most commonly used sprout suppressant on potatoes when stored at 8–12°C. Potatoes can also be stored for at least 12 weeks at either 8 or 18°C without sprouting, if tubers are dipped in hot water (57.5°C and 20 or 30 min) [5, 40]. It was reported by Hu *et al.* [40] that there were no significant differences in the pasting properties and onset (T_O), peak (T_P) and endset (T_E) temperatures of gelatinisation of sweet potato starch among heat treated (HWT) and non heat-treated samples. Peak viscosity decreased gradually and fluctuated around 310–357 RVU in variety Kanoya control samples, while it increased gradually and fluctuated around 209–308 RVU in Kanoya hot water treated samples, indicating that heat treatment reduced the peak viscosity of potato starch.

Potatoes treated with CIPC to inhibit sprouting contained greater amounts of total starch as well as resistant starch (RS) than untreated potatoes tubers [41]. Lu *et al.* [4] investigated potato varieties treated with CIPC and stored at 8°C for 5 months and found that the least shifting of gelatinization peaks to lower temperature for CIPC treated samples. Ezekiel and Singh [42] studied starch properties of potato cultivars treated with CIPC. Swelling volume of starch decreased significantly with CIPC in all varieties.

Neeraj [43] studied the effect of various sprout inhibiting treatments viz., hot water dip treatment (HWT, 57.5 ± 0.1°C for 20 min) and single spray of 50% formulation of CIPC treatments on the characteristics of starch extracted from Kufri Chipsona 4 variety of potato stored at low temperature (12 ± 1°C). It was observed that significantly higher starch yield was observed in CIPC treated tubers followed by hot water treatment and untreated. The CIPC treated tubers retained higher starch than other treatments until the end of the storage period, which can be attributed to inhibited sprouting and low respiration rates. Hot water treatment may also have resulted in higher starch yield because of its inhibitory role on sprouting of tubers. Kyriacou *et al.* [44] also observed that CIPC and HWT retained higher starch concentrations during the storage period.

There was no significant effect of HWT on particle size, however, CIPC treatment significantly increased the percentage of small size particles of starch from LT stored tubers [43]. Ezekiel *et al.* [45] reported that CIPC treated potatoes subsequently stored at 12°C for 90 days showed an increase in the proportion of small size granules. The granule diameter ranged from 18 to 25 μm.

The effects of CIPC and HWT were found to be non-significant with respect to untreated tubers for extracted starch's moisture content, protein content, fat content, crude fiber, ash content, purity, WAC and colour whiteness values; while starch yield, amylopectin, phosphorus content, swelling power, solubility, light transmittance and peak viscosity were higher for starch extracted from tubers treated with CIPC than HWT [43]. The nonsignificant effect on purity of starch was attributed to nonsignificant changes in moisture, fat, crude fibre, protein and ash contents of the starch extracted from tubers subjected to various sprout inhibiting treatments.

Hot water dip treated tubers resulted in significantly lower swelling power than untreated tubers at RT storage, however, significantly higher swelling power was observed in CIPC treated tubers stored at LT [43]. Additionally, Lu *et al.* [4] discovered that tubers treated with CIPC exhibited a greater swelling capacity of the extracted starch. The considerably increased phosphorus content of the CIPC-treated tuber starch might account for its relatively strong swelling power. The lack of internal structure produced by negatively charged phosphate ester groups inside starch granules has been attributed to potato starches' greater swelling potential [46]. Eerlingen *et al.* [47] attributed increased swelling power to the amorphous AM being transformed into a helical shape, increased contacts between AM chains, and altered interactions between crystallites and the amorphous matrix. The development of cross links in the amorphous area and consequent rise in crystallinity during HWT might possibly account for the decrease in swelling power and solubility of the extracted starch [48].

Significantly lower syneresis was observed in the starch extracted from CIPC treated tubers followed by HWT tubers and untreated tubers [43]. Singh *et al.* [14] reported that lower amylose content and high percentage of small size granules caused lower syneresis. Thus, lower amylose content and higher percentage of small size granules may be responsible for lower syneresis exhibited by the starch extracted form CIPC treated potatoes. Hu *et al.* [49] reported that HWT reduced the setback viscosity value of sweet potato starch during storage that decreased its syneresis.

Verma *et al.* [50] observed that increasing gamma (γ) irradiation dosage resulted in a substantial drop in the apparent amylose content, swelling index, enthalpy of gelatinization, transition temperature, and overall crystallinity of the starches. Similarly, increasing the ionising dosage resulted in a substantial decrease in the pasting characteristics (peak, trough, setback, ultimate viscosity, and pasting temperature) of the extracted starches. On the contrary, the enhanced solubility index of the starch was caused by gamma irradiation. Irradiation treatment increased the total free glucose content of potato and lowered the starch thermal transition and pasting temperatures. Starch crystallinity reduced substantially in irradiation potatoes, which may account for the lower resistant starch concentration.

6. Effect of storage conditions and packaging

The starch content of potatoes has been reported to decrease during storage due to conversion of starch to sugar and its utilization in respiration [51]. The rate of starch depletion and sugar buildup vary with cultivar and storage temperature, presumably due to variations in enzyme activities [52]. Johnston *et al.* [53] observed an increase in amylose to amylopectin ratio in the starch granules during storage of tubers. Golachowski [54] studied the properties of starch separated from potato tubers stored at 20°C, 8°C, 4°C and 0°C. The study included also potato tubers having been frozen, thawed and refrozen as well as potato tubers before storage. Starch separated from the stored potato tubers showed differences in chemical composition, reducing power, granularity, whiteness and viscosity as well as gelatinization temperatures in comparison with the starch separated from potato tubers before storage. Ridley and Hogan [55] reported a reduction in the viscosity of starch isolated from potatoes that were stored at 1.7 and 7.2°C for three months. Peak viscosity was reduced after 90 days of storage at 8°C but increased at 16°C, with no significant change at 4 or 12°C. Separated starches from potatoes kept at a higher temperature demonstrated increased transition temperatures and decreased pasting temperatures, and vice versa. Separated starch from potatoes kept at 8°C exhibited increased peak, trough, and breakdown viscosity, as well as a reduced setback. After storage at 4, 8, and 20°C, the fraction of large size granules decreased and the proportion of smaller granules increased.

Cottrell *et al.* [56] investigated the physicochemical properties of starch produced from several potato cultivars and kept at temperatures of 4, 8, 10, and 20°C. At harvest, the surface of the starch granules was smooth but during storage the surface of the granules became progressívely more pitted. Potato starches kept at 4°C had reduced To, Tc, and Hgel values, as well as lower transmittance values. The peak viscosity and setback of starches isolated from potatoes stored at a higher temperature (20°C) were the greatest.

Kaur *et al*. [57] reported that the starches extracted from potatoes kept at 4°C had significantly greater proportion of tiny granules, pitted with rougher surfaces lower commencement and conclusion gelatinization temperatures than those held at 8 and 20°C.

Ezekiel *et al.* [52] detected a substantial reduction in the amylose content of starch with increase storage period of tubers. Separated starch from potatoes that had been kept at a higher temperature demonstrated a lower pasting temperature. Potato starch kept at 8°C had a larger peak, trough, and breakdown viscosity, as well as a lower set-back. Peak viscosity rose as storage temperature increased, whereas swelling volume dropped. After 90 days of storage of tubers at 4°C, a substantial decrease in swelling volume but no significant changes in phosphorus content of the extracted starch were observed.

Neeraj [43] reported that as the storage time for tubers increased, the moisture, fat, ash, crude fibre, amylopectin, phosphorus, water absorption capacity, light transmittance, and peak viscosity of the extracted starch increased; while yield, purity, amylose, swelling power, solubility, syneresis, and colour whiteness value decreasedIt has been reported that pastes prepared from potato starches with higher percentages of small granules exhibit lower syneresis. The decrease in syneresis of starch extracted from stored tubers could be due to the decreased amylose, and increased amylopectin, phosphorus and percentage of small size particles [17, 18].

Neeraj [43] reported that the starch extracted from the tubers stored at low temperature (LT) with different packaging viz., nylon mesh bags or MAP or vacuum did not show significant differences in its moisture, fat, protein, ash, crude fiber, purity, amylose, amylopectin, WAC, swelling power and whiteness values; while minimum syneresis and maximum starch yield, phosphorus content, solubility, light transmittance and peak viscosity were observed for starch extracted from tubers packed in net bags followed by vacuum and modified atmosphere packaging. Significantly higher peak viscosity of starch was observed for starch extracted from net bag packed tubers followed by vacuum, while it was minimum in modified atmospheric packaging. The various packaging methods did not significantly affect the starch yield from tubers stored at room temperature, however, for tubers stored at low temperature, maximum starch yield was observed for tubers packed in net bags, while modified and vacuum packed tubers were showing at par but lower starch yields. Similarly, it was reported by Mare and Modi [58] that Taro cormels of Dumbe-dumbe and Pitshi packaged in mesh bags also displayed higher starch content compared with those packaged in polyethylene bags and boxes.

7. Conclusion

The growing starch markets have led to food industries to a constant demand for starches with specific properties that meet the demands of applicability. The quality of extracted starch form potato tubers, however, are significantly affected by environmental, cultural and storage conditions. The available information of the various physico-chemical and functional characteristics of potato starch as affected by extraction methods, varieties, curing, sprout inhibitors, and storage conditions. Some more information still need to be generated with respect to the effect of preharvest cultural practices, organic raising, extent of sprouting of tubers, application of other sprout suppressants (irradiation, isopropyl phenylcarbamate, ozone, ethylene, MH, carvones, etc) and various storage structures on the quality of extracted potato starch. The information w.r.t. verities may be helpful in identifying phenotyping trait(s) in potato breeding processes to create special potato genotypes for manufacturing of starch with the characteristics specially tuned for certain industrial processing technologies. On the basis of information, the potato starch industry may also select specifically pre- and postharvest treated stored potatoes of a given variety for extracting starches having the desired functional characteristic.

Acronyms and abbreviations

AM	amylose
AP	amylopectin
CIPC	isopropyl N-(3-chlorophenyl) carbamate
HWT	hot water treatment
LT	low temperature
RS	resistant starch
XRD	X-ray diffraction
SP	swelling power
T_E	gelatinization endset temperature
T_O	gelatinization onset temperature
T_P	gelatinization peak temperature
Tvdi	temperature at which viscosity development is initiated
WAC	water absorption capacity
PHI	peak height indices
ΔHgel	enthalpies of gelatinization.

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