# Studies on Swelling and Solubility of Modified Starch from Taro (*Colocasia esculenta*): Effect of pH and Temperature

Feroz ALAM (✉)
Abid HASNAIN

**Summary**

Several physical and chemical treatments were employed to modify Taro (*Colocasia esculenta*) starch. The effects of pH and heating temperature on their swelling powers and solubilities were studied. At 95 °C, heat-moisture treated, oxidized and acetylated starches were more soluble, while cross-linked starch was less soluble as compared to raw starch. Heat-moisture treated and chemically modified starches had lower swelling power (at 95 °C) than that of isolated starch. Swelling power and solubility were found to be a function of pH and it was observed that all these modified starches had greater swelling capacity and solubility at pH 2.0 and 10.0.

**Key words**

Taro starch, chemical modification, swelling power, solubility

Department of Food Science & Technology, University of Karachi, Karachi-75270, Pakistan
✉ e-mail: ferozalam12@hotmail.com

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## Introduction

A large number of starch resources are found in the tropic and subtropics regions which are being used as food while their properties remain to be determined. The Taro (*Colocasia esculenta*) is one of those starch rich sources. Several attempts have been made for the extraction and evaluation of its functional properties that revealed that Taro starch has some preference over other starches. Taro starch forms hard coating layer and its solution has clarity at even high solid concentration. It has high swelling power, high gel strength and peak viscosity (Adebayo and Itiola, 1998). Taro starch, in view of its small granule size (0.5-5μm) form smooth textural gel (Jirarat et al., 2006) and has been found to be easily digestible (Sugimoto et al., 1986). Due to ease of assimilation, infants and the persons with digestive problems can use Taro starch (Moy and Nip, 1983). Taro starch has also been studied as a filling agent for the biodegradable Polyethylene film and as a fat substitute (Daniel and Whistler, 1990; Jane et al., 1992).

Among the most important considerations for selecting a starch are its functional properties. The functional properties of native starch may also be improved by applying appropriate modification techniques. These modifications improve some of the inherent properties and impart new properties in native starches that make them more versatile in their applications. Chemically modified starches are used as food additives and have a broad range of applications as thickening, texturizing, bulking, stabilizing and gelling agents. Knowledge of the functional properties of Taro starch may also extend its use as a food source. There is no significant work reported on the modification of Taro starch, probably due to the difficulty in extracting the starch from fresh tubers which contain 9.1% mucilaginous material (Aboubakar et al., 2008; Hong and Nip, 1990). In an earlier study, a simple and effective isolation method (Feroz et al., 2004) has been reported. Characterization of some properties including solubility and swelling power of native taro starch has been done (Elevina et al., 2005; Jaffery et al., 2005) but no systematic study was carried out on modified taro starch. The present study was undertaken to determine certain functional properties of Taro starch and to evaluate the effects of several modification treatments on these functional properties.

## Material and methods

Taro starch was isolated using a simplified method developed by Feroz et al. (2004). All chemicals used were procured from Merck (AR Grade).

### Starch modification

Heat-moisture treatment

Two methods were employed for the heat-moisture treatment:

(i) For the first method, the heat-moisture treatment was performed according to the method of Earlingen et al. (1996) with some modifications. The moisture contents of the starch samples were brought to 15, 20, 25 and 30% (on a dry weight basis) by spraying appropriate amounts of distilled water. The samples were then heated in an oven keeping it in air-tight bottles for 15 hrs. at 100 °C and subsequently air dried at room temperature.

(ii) For the second method, 1% starch slurry in distilled water was treated for 30 min. at the desired temperatures (60, 70, 80 or 95 °C), cooled and air dried (Deshpande et al., 1982).

Oxidation

Oxidation of starch with hydrogen peroxide ($H_2O_2$) was done by the method of Robert and Peoria (1994) with some modifications. Taro starch (200 g) was dispersed in water (600 ml) containing 1 g sodium sulphate. The pH was adjusted to 11.0 by slowly adding 1M NaOH while maintaining the temperature at 25 °C. Hydrogen peroxide (50 ml of 5%) was gradually added using a burette over a period of 10 hrs. The pH was adjusted to 5.5 with 1m HCl. The reaction mixture was poured into 95% ethanol (200 ml) and stirred for 30 min. before filtration. The residue was dried over night in an oven at 45 °C.

Acetylation

Acetylation was carried out as describe by Lawal (2004).

Cross-linking

For cross-linking, method of Waliszewski et al. (2003) was followed.

### Swelling power and solubility

The solubility and swelling power of the isolated and modified starches were determined by the modified method of Lauzon et al. (1995). One gram of starch in 50 ml of distilled water was heated at the specified temperatures for 1 h while gently stirring and then centrifuged at 4,500 rpm for 30 min.

Effect of heating temperature

In order to determine the effect of heating temperature, starch solutions were heated to temperature of: 20, 40, 50, 60, 70, 80 and 90 °C for 30 min. followed by rapid cooling to room temperature using ice bath.

Effect of pH

In order to determine the effect of pH on swelling power and solubility, starch solutions were made at pH 2.0, 4.0, 6.0, 8.0 and 10.0.

## Results and discussion

### Effects of temperature on solubility

Solubility of starch was observed to be a function of temperature between 70-90 °C (Fig. 1) and pH (Fig. 2). Below the gelatinization temperature all starches (native or modified) were less soluble. Starches treated at 80 and 95°C with excessive quantity of water were more soluble compared to the native starch at these temperatures and complete gelatinization was also observed. The high solubility of these pregelatinized starches at lower temperature may be attributed to loss of granular structure and release of amylase fraction of

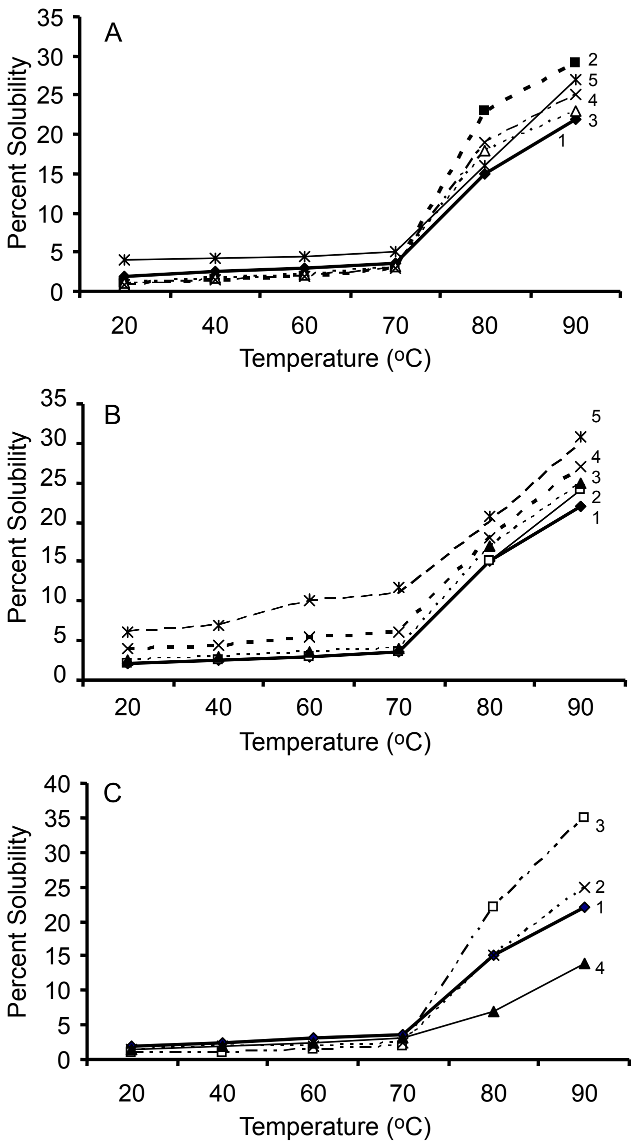


**Figure 1.** Effect of temperature on solubility of modified starches. (A - Low moisture treatment: 1 - Isolated starch, 2 - 15% moisture, 3 - 20% moisture, 4 - 25% moisture, 5 - 30% moisture; B - High moisture-heat treatment: 1 - Isolated starch, 2 - 60°C, 3 - 70°C, 4 - 80°C, 5 - 95°C; C - Chemical modification: 1 - Isolated starch, 2 - Acetylated starch, 3 - Oxidized starch, 4 - Cross-linking starch)

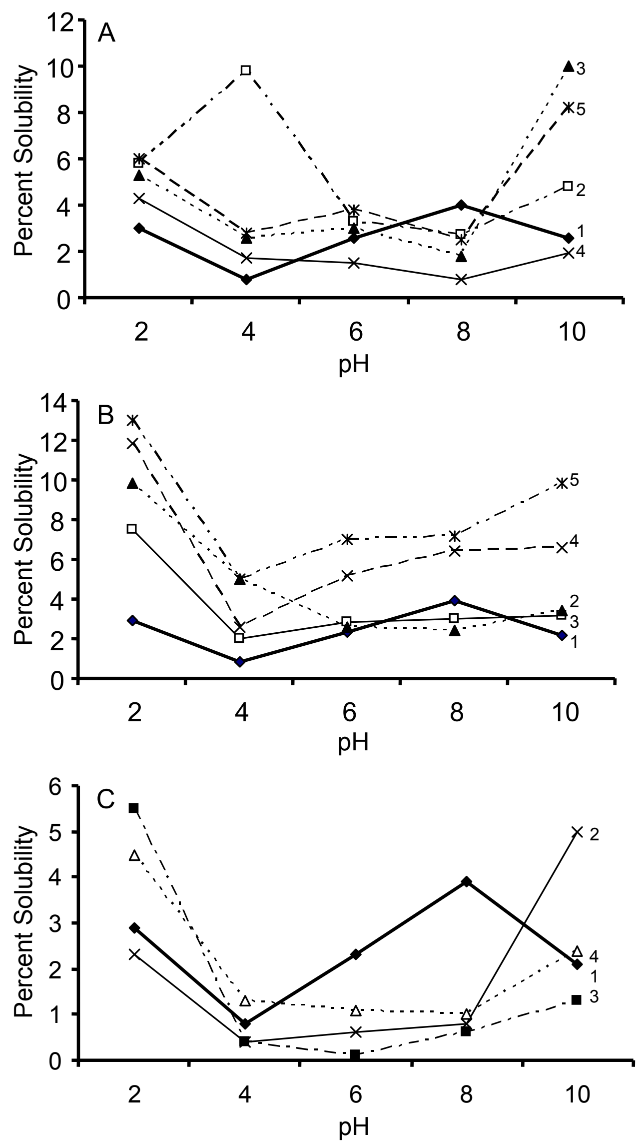


**Figure 2.** Effect of pH on solubility of modified starches. (A - Low moisture treatment: 1 - Isolated starch, 2 - 15% moisture, 3 - 20% moisture, 4 - 25% moisture, 5 - 30% moisture; B - High moisture-heat treatment: 1 - Isolated starch, 2 - 60°C, 3 - 70°C, 4 - 80°C, 5 - 95°C; C - Chemical modification: 1 - Isolated starch, 2 - Acetylated starch, 3 - Oxidized starch, 4 - Cross-linking starch)

the starch as the amylase molecules are preferentially solubilized and leached from swollen starch granules (Stone et al., 1984). The loss of granular structure, however, renders the starch less viscous. Thus, to produce a given viscosity in specific product more quantity of pregelatinized than that of untreated starch would be required.

No definite trends were observed in the solubility of low moisture-high temperature treated starches (Fig. 1A). A high temperature treatment at 20% moisture increased the solubility to a greater extent. All the low moisture high temperature treated starches were more soluble than the raw starch. The cross-linked starch was less soluble than raw starch at temperatures lower than the gelatinization temperature (Fig. 1C). Cross linking distinctly lowered the solubility of starch at all temperatures as compared to native starch. Cross-linking has been reported to inhibit solubility and swelling of starches, with the inhibition being linearly related to the degree of cross-linking (Lin et al., 2003). Cross-linked starch may be used to control texture and provide heat, acid and shear tolerance. This may provide better control over end-product quality and greater flexibility in dealing with formulations, processing or storage conditions.

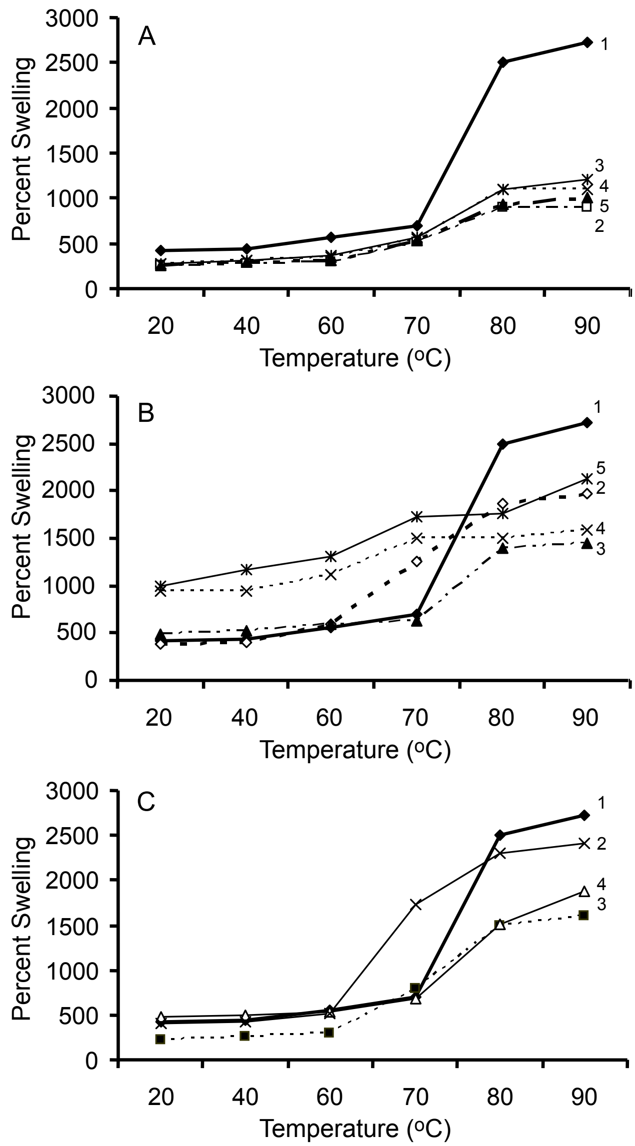


**Figure 3.** Effects of temperature on swelling of modified starches. (A - Low moisture treatment: 1 - Isolated starch, 2 - 15% moisture, 3 - 20% moisture, 4 - 25% moisture, 5 - 30% moisture; B - High moisture-heat treatment: 1 - Isolated starch, 2 - 60°C, 3 - 70°C, 4 - 80°C, 5 - 95°C; C - Chemical modification: 1 - Isolated starch, 2 - Acetylated starch, 3 - Oxidized starch, 4 - Cross-linking starch)

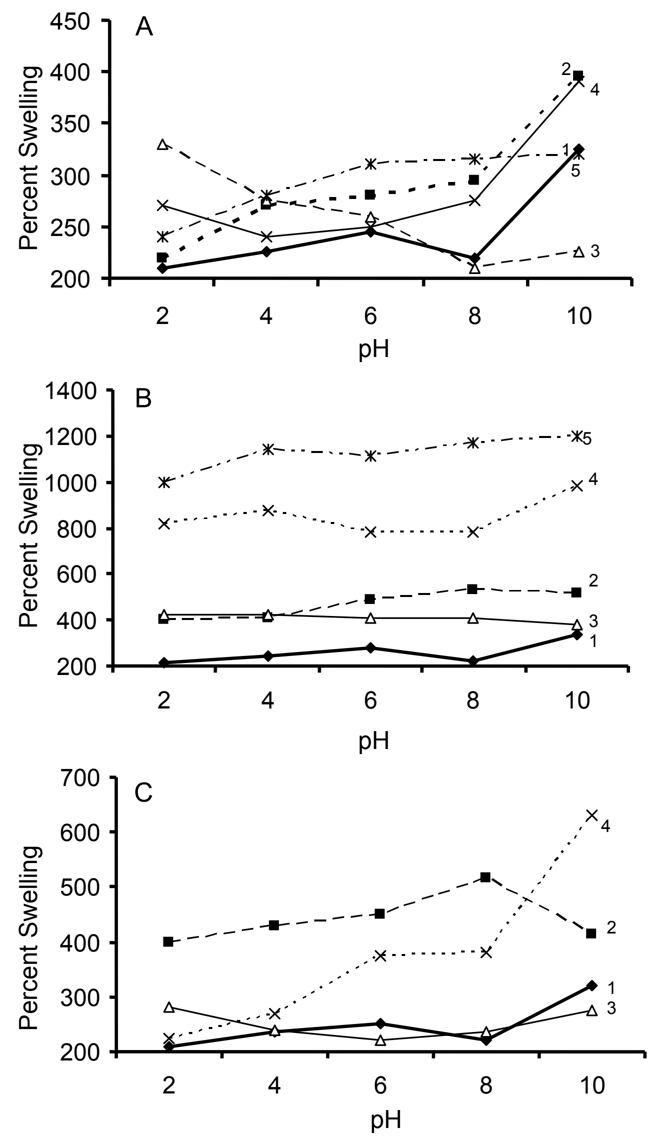


**Figure 4.** Effects of pH on swelling of modified starches. (A - Low moisture treatment: 1 - Isolated starch, 2 - 15% moisture, 3 - 20% moisture, 4 - 25% moisture, 5 - 30% moisture; B - High moisture-heat treatment: 1 - Isolated starch, 2 - 60°C, 3 - 70°C, 4 - 80°C, 5 - 95°C; C - Chemical modification: 1 - Isolated starch, 2 - Acetylated starch, 3 - Oxidized starch, 4 - Cross-linking starch)

Both acetylation and oxidation increased starch solubility. However, the effect of oxidation was more pronounced than the acetylation. Oxidation is known to weaken starch granule which may lead to the oxidized starch being more soluble than native starch (Robert and Peoria, 1994).

**Effects of pH on solubility**

The modified starches, in general, were more soluble at extreme pH values (pH 2.0 and 10.0) than the native starch (Fig. 2A-C). Minimum solubility for most starches was observed at pH 4.0 and 6.0. The high solubility of starches under highly acidic conditions (pH 2.0) may have been due to their enhanced hydrophilic character and partial hydrolysis. Under alkaline conditions, the starch may undergo partial gelatinization, thus resulting in higher solubility at pH 10.0 (Olayide, 2004). The increased solubility of modified starches at pH 10.0, compared to that of the isolated starch may be attributed to the weakening of granule structure during modification. Such changes in starch granule stability during modification may render them more soluble under highly alkaline conditions than the raw starch. In acetylated starch, solubility increased progressively as the pH increased from 2 to 10. It is noteworthy that solubility also increased as pH was reduced in the acidic medium.

**Effects of temperature on swelling power**

The swelling of starch was found to be a function of temperature (Fig. 3A-C), and it followed a pattern similar to that of solubility characteristics. Prior to gelatinization, there was some increase in swelling capacity of starches. However, once the gelatinization process sets in, swelling increased rapidly with increasing temperature. Both the low moisture-high temperature (Fig. 3A) and high moisture-high temperature (Fig. 3B) treatments reduced swelling appreciably at 80 and 90ºC. At higher temperature (80 and 90 ºC), the chemically modified starches had lower swelling than the native starch (Fig. 3C). These trends maybe related to the changes in surface characteristics of starch granules. The low moisture-high temperature treatment may induce packing in starch granules rendering them more prone to a loss of structure and to the leaching of starch fractions. At higher temperatures, these starches loss their granular structure faster than the raw starch, resulting in a low swelling capacity. Continuous heating increases the mobility and collision of swollen granules and amylase molecules (Chang et al., 1995). The partial solubilization of amylase during the high moisture-high temperature treatment below the gelatinization temperature of starch may help in absorption of more water. All the high moisture-high temperature, up to 70 ºC, treated starches thus showed greater swelling than the native starch. At 80 and 90 ºC, however, these starches swelled less than the control did. This may occur partly because the granule structure is essentially lost during gelatinization at temperature higher than the gelatinization temperature of starch. Under the test conditions, native starch would swell more as it has more amylose embedded in the starch granules to absorb moisture. It also has a greater capacity for swelling as it may reach its gelatinization point without releasing much of its starch contents into the surroundings. This effect was more pronounced in oxidized starch than acetylated starch. Higher swelling indicates a lowering of associative force between the granules and hence Taro starch appears to undergo some reduction in associative forces due to oxidation. The oxidizing agent has also been claimed to penetrate deeply into the granule, acting mainly on the amorphous region (Forssel et al., 1995). The inhibition of swelling as a result of cross-linking is well known (Waliszewki et al., 2003) and is attributed to a tight packing of molecules in the granule and a substantial degree on inter-molecular bridging during the cross-linking process. Increasing the degree of cross-linking decreases the ability of the granule to swell and also decrease its viscosity.

**Effects of pH on swelling power**

The swelling of starch was observed pH dependent (Fig. 4A-C).The swelling of isolated raw starch increased with increasing pH. Similar trend was also observed for the low moisture-high temperature (Fig. 4A) and high moisture-high temperature (Fig. 4B) treated starches. Only the starch treated at 20% moisture level and at high temperature showed a decreasing swelling capacity as the pH was increased. It is noteworthy that acetylated starch showed improved swelling of starch at any pH value. Cross-linking of starch resulted in increased swelling as the pH increased. Cross-linked starch also had the greatest swelling capacity at pH 10.0 compared to native, acetylated or oxidized starches.

## Conclusion

The solubility of both native and the modified Taro starches greatly increased at high temperatures (80 and 90 ºC). At 90 ºC, heat-moisture treated, acetylated and oxidized starches were more soluble than that of raw starch. Cross-linked starch was less soluble compared to raw starch. The modified starches had greater swelling capacity and solubility at pH 2.0 and 10.0. Heat-moisture treated and chemically modified starches had lower swelling capacity at 90 ºC than that of raw Taro starch. The rapid solubilization of pregelatinized starches will be useful in foods such as instant pudding, pie fillings, soups and cake frosting.

## References


Aboubakar Y. N., Njintang J., Scher., Mbofung, C. M. F. (2008). Physicochemical, thermal properties and microstructure of six varieties of taro (*Colocasia esculenta* L. Schott) flours and starches. J Food Engg 86(2): 294

Adebayo A. S., Itiola O. A. (1998). Properties of starches obtained from *Colocasia esculenta and Artocarpus communs.* Nigerian J Natural Prod Med 02: 29

Chang Y. L., Shao Y. Y., Tseng K. H. (1995). Gelation mechanism and rheological properties of rice starch. Cereal Chem 72(4): 339

Daniel J. R., Whistler R. L. (1990). Fatty sensory qualities of polysaccharides. Cereal Foods World 35: 825

Deshpande S. S., Sathe S. K., Rangnekar P. D., Salunkhe D. K. (1982). Functional properties of modified black gram (*Phaseolus mung L.*) Starch. J Food Sci 47: 1582

Eerlingen R. C., Jacobs H., Win V., Delcour J. A. (1996). Effect of hydrothermal treatment on the gelatinization properties of potato starch as measured by differential scanning calorimetery. J Thermal Analysis 47: 1229

Elevina P., Forrest S. S., Emeratriz P. D. (2005). Characterization of some properties of starches isolated form *Xanthosoma sagittifolium (tannia) and Colocaisa esculenta (taro).* Carbohyd Polymers 60: 139

Feroz A. J., Khalid J., Abid H. (2004). Extraction starch from taro (*Colocasia esculenta)* by freeze-thaw method. Pak J Food Sci 14 (2): 1

Forssel P., Hamunen A., Autio K., Suortti T., Poutanen K. (1995). Hypochlorite oxidation of barley and potato starch. Starch/ stärke 47: 371

Hong G. P., Nip W. K. (1990). Functional properties of precooked taro flour in sorbets. Food Chem 36: 261

Jaffery F. A., Hasnain A., Jamil K., Abbas T. (2005). Isolation, determination and characterization of taro (*Colocasia esculenta*) starch. Pak J Sci Ind Res 48(4): 292

Jane J., Shen L., Chen J., Lim S., Kasemsuwan T., Nip W. K. (1992). Physical and chemical studies of taro starches and flours. Cereal Chem 69(5): 528

Jirarart T., Sukruedee A., Persuade P. (2006). Chemical and physical properties of flour extracted from Taro (*Colocasia esculenta*) grown in different regions of Thailand. Sci Asia 32: 279

Lawal O. S. (2004). Composition, physicochemical properties and retrogradation characteristics of native, oxidized, acetylated and acid-thinned new cocoyam (*Xanthhosoma sagittifolium)* starch. Food Chem 87: 205

Lauzon R. D., Shiraishi K., Yamazaki M., Swayama S., Sugiyama N., Kawabata A. (1995). Physiochemical properties of cocoyam starch. Food Hydrocoll 9 (2): 77

Lin J. H., Lee S. Y., Chang Y. H. (2003). Effect of acid-alcohol treatment on the molecular structure and physicochemical properties of maize and potato starches. Carbohyd Polymers 53(4): 475

Moy J. H., Nip W. K. (1983). Processed food. In Taro: A review of *Colocasia esculenta* and its potentials. J. K. Wang ed. University of Hawaii Press, Honolulu

Olayide S. L. (2004). Succinyl and acetyl starch derivatives of a hybrid maize: physicochemical characteristics and retrogradation properties monitored by differential scanning calorimetry. Carbohyd Res 339(16): 2673

Robert E. W., Peoria I. (1994). Oxidation of starch by thermo-chemical processing. Starch/stärke 46(11): 414

Stone L. A., Loenz K., Collins F. (1984). The Starch of Amaranthus: physiocochemical properties and functional characteristics. Starch/stärke 36 (7): 232

Sugimoto Y., Nishihara K., Fuwa H. (1986). Some properties of taro and yam starches. J Jap Soci Starch Sci 33: 169

Waliszewski K. N., Aparicio M. A., Bello L. A., Monroy J. A. (2003). Changes of banana starch by chemical and physical modification. Carbohyd Polymers 52(3): 237

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