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Extraction of Starches from Tuber Crops Using Ammonia*

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ABSTRACT

Ammonia solution (0·03 M) was used to extract starch from various tuber crops by the conventional settling method. It was found that there was noticeable improvement in the yield of starch from Colocasia *(6–16%), while it fell for sweet potato starch and remained almost the same for the other starches. The various properties of starch, thus extracted, were compared with those for starch obtained by water extraction. It was found that total amylose of all starches were unaffected while the 'soluble amylose' was slightly suppressed for* Colocasia *starch extracted with ammonia solution. Peak viscosity was found to be increased to a large extent for* Colocasia *and* Dioscorea esculenta *starches by ammonia extraction, while it was lowered for sweet potato starch. The swelling volume of* Colocasia *starch extracted with ammonia was similarly enhanced by 25%, but the* Dioscorea esculenta *starch did not show such a tendency. Sweet Potato starch suffered a reduction in swelling volume. Phosphorus content was found to be independent of the extraction medium.*

INTRODUCTION

The tropical tuber crops are an important food in the humid tropics because of their high carbohydrate content which is mainly in the form of starch (Cillie & Joubert, 1950; Onweume, 1978; Gallant *et al.*, 1982).

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Industrial applications based on starch for these crops have been also increasingly recognised. Though cassava has been processed to give starch for many years, extraction of starch from the other tubers has not received much attention. The main reason is the difficulty experienced in extraction of starch from tuber crops other than cassava. Cassava is unique in that it contains over 80% of starch on a dry weight basis with little protein, fibre or other polysaccharides. Hence the starch settles fast and can be easily obtained in a pure white form. Sweet potato starch often has a dull colour, probably due to colouring matters present in the skin and hence its extraction involves the use of dilute alkali which flocculates the impurities and dissolves colouring matter (Paine *et al.*, 1938; Radley, 1976). In the case of other tuber crops, especially *Colocasia*, presence of mucilaginous material is a major hurdle in starch extraction. Settling takes a very long time, which can result in microbial contamination and hence a reduction in starch quality.

Dioscorea and *Colocasia* starches have special properties like high gel strength and low granule size which make them suitable for specific applications (Coursey, 1967; Griffin & Wang, 1983). Hence an easy and convenient method is desirable for extraction of these starches to produce good quality starch in good yield. An attempt has been made to use an ammonia solution instead of water for extraction of different starches and the results are given in this paper.

EXPERIMENTAL

Tubers of cassava, *Colocasia*, *Xanthosoma*, *Dioscorea alata*, *Dioscorea esculenta*, *Dioscorea rotundata* and sweet potato were obtained from the CTCRI farm. The accessions/cultivars of the different tubers from which the starch was extracted and the stage of harvest of the tubers are given in Table 1.

Starch extraction was carried out using the standard procedure (Badenhuizen, 1964) using tap water or ammonia solution (0·03 M). Freshly harvested tubers were washed and peeled. For cassava, the rind was also removed. The tubers were cut into small pieces of approx. 50 × 10 × 10 mm and washed again. A 1 kg sample of the pieces was washed and steeped in water or ammonia solution for 2–3 min. The pieces were disintegrated in a Remi Mixie for 1 min at low speed in the presence of sufficient water or dilute ammonia solution to cover the pieces. The pulp was allowed to remain in solution for approximately 2 h before filtration. Filtration was carried out successively through 80 mesh and 260 mesh sieves. The filtrate was allowed to settle for 24 h for

TABLE 1
Accessions/Cultivars of Different Species Used for Starch Extraction and their Stage of Harvest

Species	*Cultivars/Accessions*	*Stage of harvest*
Cassava	Cultivar: Sree Visakam	10 months
Colocasia esculenta	Cultivar: C-9	7 months
Sweet potato	Cultivar: Kanhangad local	105 days
Dioscorea alata	Accession: Da 80	10 months
Dioscorea esculenta	Cultivar: Sree latha	10 months
Dioscorea rotundata	Cultivar: Sree Subhra	10 months
Xanthosoma saggittifolium	Accession: Xa 38	10 months

cassava and sweet potato, and for 48 h for the other starches which contain larger qualities of mucilaginous material. The liquid portion was decanted to leave the starch as a cake. It was collected, powdered and dried in an oven at 40–60°C. The starch, after drying, was collected and stored in polythene bags and the properties studied by withdrawing samples from these bags. For calculating the yield of starch, three extractions were carried out for each species.

The blue values corresponding to total and soluble amyloses were determined according to standard procedures (Sowbhagya & Bhattacharya, 1971; Shanti *et al.*, 1980) using six replicates for each sample. The viscosity of the starch was monitored using a Brabender viscoamylograph fitted with a 350 cmg cartridge for all the studies. The concentration of the starch used was 5% for cassava, *D. alata* and *D. rotundata* starches, and 6% for the other starches in order to maintain viscosity levels in the same range. Distilled water was used for making the starch suspension and one run was carried out for each sample. The pasting temperature was obtained from the viscosity curves. The swelling volumes were obtained by the procedure of Schoch (1964), based on three replications for each sample and phosphorus content by the vanadomolybdate method (Smith & Caruso, 1964).

RESULTS AND DISCUSSION

In earlier experiments in our laboratory, various chemicals have been tried to improve the extractability of starch, especially from the tubers of *Colocasia* and *Dioscorea* spp. (CTCRI, 1987). These include 10% ethyl alcohol, 1% calcium hydroxide solution, 1% cetyl trimethylammonium bromide solution and 1% acetic acid. Among these, only calcium hydroxide solution was found to improve the settling of *Colocasia* starch, but the starch obtained assumed a brownish colour, which could not be removed even by repeated washings. Hence a mixture of alcohol and calcium hydroxide solution was tried, but was found to be ineffective. Cetyl trimethylammonium bromide was not only ineffective, but also led to changes in starch properties. Use of water at 50°C did not lead to any improvement in yield of *Colocasia* starch. However, dilute ammonia solution was found to improve the settling of starch from *Colocasia* and *Dioscorea* sp. Preliminary experiments also showed that the desirable concentration of the ammonia solution is 0·03 M. Table 2 gives the yield of dry starch from different tuber crops on using water and dilute ammonia solution. The data indicate that in the case of *Colocasia*, the yield of starch was considerably improved from 6·2 to 16·6% under identical conditions, when 0·03 M ammonia solution is used instead of water. The other tuber crops except sweet potato also showed marginal improvement in yield but with sweet potato, the yield was slightly depressed.

Colocasia contains the largest quantity of mucilage and hence it is most difficult to extract starch from these tubers. The settling of starch is too slow leading to a reduction in yield and also the chance of microbial degradation while settling for 1–2 days. Therefore, the noticeable

TABLE 2

Yield, Total and Soluble Amylose Contents (Blue Values) for Starches Extracted with Ammonia Solution and Water

Species	*Extraction medium*	*Yield (%)*	*Total amylose (Blue value)*	*Soluble amylose (Blue value)*
Cassava	Water	21·8 ± 0·54	0·37 ± 0·012	0·17 ± 0·012
Cassava	NH_3	22·2 ± 0·37	0·37 ± 0·013	0·17 ± 0·019
Colocasia	Water	6·2 ± 1·79	0·28 ± 0·006	0·17 ± 0·011
Colocasia	NH_3	16·2 ± 0·37	0·26 ± 0·010	0·14 ± 0·017
Dioscorea alata	Water	17·0 ± 1·43	0·45 ± 0·01	0·18 ± 0·008
Dioscorea alata	NH_3	18·3 ± 1·0	0·44 ± 0·027	0·18 ± 0·010
Dioscorea esculenta	Water	17·7 ± 1·06	0·29 ± 0·013	0·13 ± 0·004
Dioscorea esculenta	NH_3	18·7 ± 1·14	0·28 ± 0·017	0·13 ± 0·008
Dioscorea rotundata	Water	18·8 ± 0·85	0·40 ± 0·013	0·16 ± 0·010
Dioscorea rotundata	NH_3	19·5 ± 1·16	0·40 ± 0·010	0·16 ± 0·013
Sweet potato	Water	13·0 ± 1·02	0·34 ± 0·010	0·15 ± 0·008
Sweet potato	NH_3	10·9 ± 1·10	0·35 ± 0·013	0·15 ± 0·013
Xanthosoma	Water	20·0 ± 0·32	0·38 ± 0·01	0·23 ± 0·014
Xanthosoma	NH_3	20·5 ± 1·76	0·36 ± 0·005	0·24 ± 0·015

increase in yield on the use of ammonia solution can be used for large-scale extraction of starch followed by a conventional settling process. The starch of *Colocasia* has special properties in particular a very small granule size (1–10 μm) and easy digestibility (Potgeiter, 1940; Wang, 1983). In view of its small size, the starch has applications in cosmetic preparations (Griffin & Wang, 1983; Higashihara, 1983). In Hawaii, taro starch has been used in the production of biodegradable polythene bags (Higashihara, 1983). Increased utilisation in food and industry could stimulate a higher production.

There is no sizable increase in the yield of starch from other tuber crops, and this could be due to the fact that the mucilage content is lower, especially cassava, which is practically devoid of it. However, the reason for the yield reduction in the case of sweet potato starch is not clear. Though the yield may not be increased, ammonia extraction has the added advantage that a longer settling time can be allowed without causing microbial contamination. The pH of the extraction medium is 9·0–10·0, and the normal mould, yeast and bacteria are generally unable to grow under these conditions (Frazier, 1967).

To find out whether the use of ammonia during sedimentation affects the starch quality, various properties of the starch obtained by this procedure were compared to those of starch extracted by normal water extraction. The 'Blue Values' corresponding to total and soluble amylose are presented in Table 2. It is seen that there is no noticeable difference in total amylose content on ammonia extraction for any of the starches. But in the case of soluble amylose, the value is reduced for *Colocasia* starch alone on ammonia extraction. There is no clear idea about the structure of 'soluble amylose', but our earlier results have indicated this material may possess a net negative charge. Ammonia may be complexing with this fraction and hence the lower value for soluble amylose. The noticeable reduction in soluble amylose content in *Colocasia* starch may indicate the higher anionic nature of its soluble amylose which is in agreement with the results obtained on treatment of the starch with the surfactant, cetyl trimethylammonium bromide.

The Brabender viscosity profile of ammonia-extracted starch was compared with starch obtained by water extraction. The results, given in Table 3, show that peak viscosity is enhanced for all starches except sweet potato. In the case of *Colocasia* and *D. esculenta* starches, the enhancement is even more pronounced. Viscosity can be considered as a measure of the strength of starch granules, since a higher viscosity indicates that starch granules are intact, while the starch which has undergone chemical and microbiological damage, loses viscosity. Hence ammonia treatment not only has no chemical effect on starch but also

TABLE 3
Viscosity of Starches Extracted by Water and Ammonia

Species	*Concentration used (%)*	*Extraction medium*	PV[a] *BU*	V_{97}[b] *BU*	V_H[c] *BU*	V_C[d] *BU*	*Pasting temperature (°C)*
Cassava	5	NH_3	550	420	280	400	71-90
Casava	5	Water	480	420	180	380	70-90
Colocasia	6	NH_3	540	520	420	540	79-83
Colocasia	6	Water	420	400	380	400	79-88
Dioscorea alata	5	NH_3	500	320	550	650	83-97
Dioscorea alata	5	Water	400	300	420	600	83-97
Dioscorea esculenta	6	NH_3	800	700	820	950	80-97
Dioscorea esculenta	6	Water	580	560	540	620	79-97
Dioscorea rotundata	5	NH_3	530	450	360	550	84-97
Dioscorea rotundata	5	Water	480	400	300	420	83-97
Sweet potato	6	NH_3	180	120	100	100	81-84
Sweet potato	6	Water	340	340	320	360	81-84
Xanthosoma	6	NH_3	480	470	480	600	80-86
Xanthosoma	6	Water	470	470	480	550	81-87

[a]PV — peak viscosity.
[b]V_{97} — viscosity at 97°C.
[c]V_H — viscosity after holding at 97°C for 30 min.
[d]V_C — viscosity after cooling to room temperature.

helps in preventing possible microbial damage leading to deterioration in quality especially during settling. This is very significant for *Colocasia* where normal settling takes a long time and makes it highly susceptible to microbial damage resulting in the noticeably lower viscosity for water-extracted starch. Sweet potato behaves totally differently, the reason for this is unknown. The breakdown in viscosity, viscosity on cooling to room temperature, follows the usual pattern and no difference could be noticed between ammonia-extracted and water-extracted starches (Table 3).

Swelling volume of starches is also affected by various chemicals (Krog, 1973; Moorthy, 1985) and hence the swelling volume of starches extracted with ammonia solution was compared with that of water-extracted starches. The swelling volume of *Colocasia* starch was increased on using ammonia solution for extraction, while it fell for sweet potato starch and did not show any noticeable change for other starches (Table 4). The high viscosity increase observed in the case of ammonia extracted *D. esculenta* starch was not reflected in its swelling

TABLE 4
Swelling Volume and Phosphorus Content of Starch Extracted with Ammonia and Water

Starch	*Medium*	*Swelling volume (ml/g)*	*Phosphorus content (ppm)*
Cassava	NH_3	40·0 ± 0·81	42 ± 1·86
Cassava	Water	41·2 ± 0·57	38 ± 2·20
Colocasia	NH_3	27·5 ± 0·47	60 ± 1·74
Colocasia	Water	21·5 ± 0·22	70 ± 3·62
Dioscorea alata	NH_3	19·5 ± 0·23	165 ± 7·4
Dioscorea alata	Water	18·5 ± 0·22	170 ± 4·0
Dioscorea esculenta	NH_3	24·5 ± 0·23	172 ± 4·2
Dioscorea esculenta	Water	24·2 ± 0·24	170 ± 3·9
Dioscorea rotundata	NH_3	22·0 ± 0·31	120 ± 5·6
Dioscorea rotundata	Water	21·8 ± 0·21	120 ± 3·7
Sweet potato	NH_3	18·7 ± 0·40	75 ± 2·6
Sweet potato	Water	24·0 ± 0·21	75 ± 5·7
Xanthosoma	NH_3	25·5 ± 0·23	50 ± 6·6
Xanthosoma	Water	25·5 ± 0·23	48·5 ± 3·5

volume. Higher swelling indicates a lowering of associative forces between the starch granules, and hence *Colocasia* starch appears to undergo some reduction in associative forces on extraction using ammonia solution, but the associative force is not weakened enough to lead to granule breakdown, as indicated by the viscosity data. But in case of sweet potato starch, considerable disruption of associative forces seems to take place on extraction with ammonia solution.

Since *Colocasia* starch was found to lose its 'soluble amylose' on extraction with ammonia, which may be due to presence of anionic groups in this fraction, the phosphorous content of starch obtained by water extraction and ammonia extraction was compared. Though a variation between different starches was observed, there was no difference between ammonia- and water-extracted starches (Table 4) indicating that the phosphate linkages may not be responsible for the observed differences in case of *Colocasia* starch.

The results point out that ammonia extraction will be useful for obtaining starch from different tuber crops, except sweet potato, without affecting the properties but at the same time offering good yields. In the case of *Colocasia* starch, which is most difficult to extract, the treatment had definite advantages in increasing yield and also quality of starch. In view of the special properties of *Colocasia* starch, the large scale extraction on industrial scale may also be carried out using a low concentration ammonia solution.

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REFERENCES

Badenhuizen, N. P. (1964). *Methods in Carbohydrate Chemistry*, Vol. 4. Academic Press, New York.
Cillie, G. G. & Joubert, F. J. (1950). *J. Sci. Food Agric.*, **1**, 355.
Coursey, D. G. (1967). *Yams*. Longman, London.
CTCRI (1987). Annual Report. Central Tuber Crops Research Institute. Trivandrum, India.
Frazier, W. C. (1967). *Food Microbiology*. McGraw Hill Publishing Co. Ltd, New Delhi, pp. 8,28,41.
Gallant, D. J., Bewa, H., Buy, Q. H., Bouchet, B., Szylit, O. & Sealy, L. (1982). *Staerke*, **34**, 255.
Griffin, G. J. L. & Wang, J. K. (1983). In *Taro*, ed. J. K. Wang. University of Hawaii Press, Honolulu, p. 306.
Higashihara, M., Umeki, M. & Yamamoto, T. (1975). *J. Japan Soc. Starch Sci.*, **22**, 61.
Krog, N. (1973). *Staerke*, **25**, 22.
Moorthy, S. N. (1985). *J. Agric. Food Chem.*, **33**, 1227.
Onweume, I. C. (1978). *The Tropical Tuber Crops*. ELBS and John Wiley & Sons, Chichester, UK.
Paine, M. S., Thurber, F. H., Batch, R. T. & Richiee, W. R. (1938). *Ind. Eng. Chem.*, **30**, 1331.
Potgeiter, M. (1940). *J. Amer. Dietet. Assoc.*, **16**, 536.
Radley, J. A. (1976). *Starch Production Technology*. Applied Science Publishers Ltd, London.
Schoch, T. J. (1964). *Methods in Carbohydrate Chemistry*, Vol. 4. Academic Press, New York.
Shanty, A. P., Bhattacharya, K. R. & Sowbhagya, C. M. (1980). *Staerke*, **32**, 409.
Smith, R. J. & Caruso, J. L. (1964). *Methods in Carbohydrate Chemistry*, Vol. 4. Academic Press, New York.
Sowbhagya, C. M. & Bhattacharya, K. R. (1971). *Staerke*, **23**, 53.
Wang, J. K. (1983). In *Taro*, ed. J. K. Wang. University of Hawaii Press, Honolulu, p. 4.