Storage Qualities of Extruded Taro Products

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Abstract

Several extruded products (rice, noodle and macaroni) were prepared from taro flour (*Colocasia esculenta* L. Schott, var. Bun-long) with 30% dough moisture for storage quality studies. Some samples were enriched with 15% soy protein or 15% mungbean flour (w/w) prior to extrusion. Extruded samples were air dried (38°C for 8 hrs), packed in polyethylene bags and stored at: 2°C, 90 ± 5% R.H.; 21°C, 70 ±10% R.H.; 38°C, 33 ± 3% R.H.; and 55°C, 10 ± 1% R.H. Those stored at 2°C were considered as control.

After 12 months of storage, all of the samples stored at 55°C developed a toasted flavor and were judged unacceptable by the taste panel, while those stored at lower temperatures were judged acceptable. With some exceptions, the heat in the 55°C storage increased the chewiness of the products when cooked; degraded the main pigment anthocyanin by changing the products from purple to brown; and dehydrated the samples from the initial moisture of 8-12% to less than 4%. The higher storage temperatures (38° and 55°C) also affected the product acidity by changing the pH from an initial value of 6.2 (avg.) to 5.5-6.0 after 12 months. This change was more pronounced in the mungbean flour enriched taro rice. Overall, these extruded taro products were judged acceptable and stable when stored at temperature at 38°C or below.

Introduction

Taro has been an important root crop widely grown in different parts of the world for more than 2,000 years (Whitney *et al*, 1939). However, only in Egypt, the Philippines, Hawaii and some Pacific and Caribbean Islands is taro a commercial crop (Engel, 1975). The Hawaiians cooked and pounded the taro corms into a paste which is called "poi," and is still extensively eaten throughout the Hawaiian Islands. It was the "staff of life" of the old Hawaiians, and has been an important source of carbohydrates in many South Pacific Islands (de la Peña, 1975).

Plucknett *et al.* (1970) suggested that among all the root crops, taro has an excellent potential for solving the current shortage of world food supply. In an Ad Hoc Panel Report of the Advisory Committee on Technology Innovation, National Academy of Science, taro was indicated as an underexploited tropical root crop with promising economic value (Engel, 1975). The delivery of calories from root crops to the consumer, especially taro, is important because they provide the highest amount of calories per unit area of land. In terms of food preservation, the taro corms have great potential because they can be dried and stored under non-ideal conditions.

Previous studies in our laboratory (Moy *et al,* 1977, 1979) identified the problems in dehydration and processing of taro which would affect the palatability and storage stability of dried, intermediate products such as slices and flour. Experimental results showed, that these products were stable at 38°C for over a year. As a staple food, taro has the following characteristics: ease of digestibility of the starch granules, high energy value, high vitamin B contents, high calcium, phosphorus and iron contents, alkalinity of taro ash, and non-allergenicity. The concept of developing stable, convenient forms of taro products acceptable to consumers in the tropics and subtropics, such as rice, noodle or macaroni, was thought to be appropriate to further carrying out our plan of taro processing studies. Research into the variables in the extrusion process such as the effects of dough temperature and dough moisture content during mixing of ingredients, and protein enrichment on the extrudability of taro flour and the quality of the finished products has been reported recently (Moy *et al,* 1979). The main objective of this study was to determine the quality and acceptability of taro rice, taro noodle and taro macaroni stored for a 12-month period under four different conditions.

Materials and Methods

Bung-long-woo, commonly known as Chinese taro, was the test material used. This variety of taro is distinguished by its dark green petiole slightly tinged with reddish-purple on the upper half and conspicuously purple at the apex, dark green ovate shaped leaf blades, and cream-colored skin corm with white flesh and conspicuous purple fibers (Whitney *et al.*, 1939).

Taro corms harvested from the Island of Hawaii were shipped to Honolulu. Bags containing 20 kg of taro corms were donated and sent by C. Brewer Company for experiments. The corms were washed, peeled, and sliced into 5mm thick for air drying at 60°C for 7 hrs. The dried slices were ground with a Fitzmill (W. J. Fitzpatrick Co., Chicago, IL) into 60 mesh taro flour. The taro flour was later used in the extrusion study.

Commercially available mung beans and soy protein (Supro 610, Ralston Purina Co., St. Louis, MO) were used as protein supplements. Commercial grade mung beans were sorted and ground into flour of 40 to 60 mesh in the pilot plant.

Preparation of Extruded Samples. Plain and enriched extruded taro products were made by first mixing the taro flour with 15% of mung bean flour or soy protein, then adding the calculated amount of water, 30% (wet weight basis) at 21°C to the mixture. The dough after being mixed in the mixing chamber of the extruder for 5 min at high speed, was extruded into rice, noodle or macaroni form. There was no heating of the worm housing. The extruder used was a 12 kg/hr DEMACO laboratory press extruder by De Francisci Machine Corp. (Brooklyn, NY).

Storage of Extruded Samples. The extruded taro products were packaged in polyethylene bags and stored under 4 conditions: 2°C, 90 ± 5% R.H.; 21°C, 70 ± 10% R.H.; 38°C, 33 ± 3% R.H.; and 55°C, 10 ± 1% R.H. for 12 months, those stored at 2°C being considered as control. The second condition simulates U.S. supermarket conditions, the third represents severe tropical temperature and the fourth represents areas of extreme heat.

The following tests were conducted on the extruded taro products as measurements of extrudability and product quality.

Eating Quality. To evaluate the flavor and acceptability of extruded taro products, a taste panel was conducted using the multiple comparison test. Extruded taro products were first boiled in water until cooked and tender. The cooking time for extruded taro rice, macaroni and noodle were 8, 4, and 2 min , respectively. The cooked samples were drained and rinsed with cold water for 30 sec. A trained panel of 12 judges from the Food Science and Technology Department, University of Hawaii was served 3 separate sets of cooked samples at a sitting. A set consisted of 2 samples of extruded taro rice with added protein plus the plain taro rice. Samples of extruded taro macaroni and noodle were tested similarly. A hedonic scale of 7 was used for the ranking which ranged from 7 (the most) of a tested characteristic to 1 (the least) of the same characteristic. Triplicate runs were made for each sample.

Anthocyanin Pigments vs Brown, Degraded Pigments. Anthocyanin is the major pigment in taro. The absorbance of an ethanol extract of a sample of dried, extruded taro product was measured at 520 nm and 422 nm with a Bausch & Lomb Spectronic 88 (Rochester, NY) to compare the ratio of red anthocyanin pigment vs. brown degraded anthocyanin pigment (Sastry and Tischer, 1952). Duplicates were tested for each sample.

Objective Color Measurements. The Hunter Color and Color Difference Meter Model D25D2A, Hunter Assoc. Lab., Inc., Bethesda, MD) was used to record the reflectance of cooked, extruded taro rice products. Standardized against a standard plate (L = 31.8; "a" = 0.7; "b" = -0.3), reflectance measurements were run on the cooked samples placed in plastic petri dishes. Duplicates were tested for each sample.

Moisture Determination. To measure the stability of stored, dried, extruded taro products, 2 g of each sample were ground up in a Waring Blender and put into aluminum dishes for drying at 137°C in a natural convection air oven. The dishes were cooled in a dessicator and weighed at hourly intervals until there was no further weight change. The residual moisture was calculated on wet weight basis.

pH. Two grams of ground extruded taro samples were mixed thoroughly with 20 ml of distilled water and allowed to stand for 30 min. The pH was measured with a Corning Model-10 pH meter.

Texture Measurement. Triplicates of 10 g of cooked taro samples prepared the same way as in the taste panel were used for texture measurements with a texture tester (Model TT-2), by PEP Inc. (Houston, TX). Results are reported as the work (kg-cm) required to shear and compress a sample in the test cell.

Protein Content. The automated total nitrogen analysis by Schuman *et al* (1973) was used to determine the protein content of stored, extruded taro samples. Samples were ground and placed in the digestion tube along with 3.5 g of prepared catalyst (96% K_2SO_4, 3% $CuSO_4$, 3% $CuSO_4$, and 1% pumice). A Technicon Auto-Analyzer was used for the analysis.

Results and Discussion

Eating Quality. Extruded taro products stored for 12 mos at 4 different temperatures, 2, 21, 38, and 55°C, were tested for flavor, texture and acceptability by 12 panel judges. The results are shown in Tables 1, 2 and 3.

As shown in Table 1, significant flavor changes were found in all the extruded taro products stored at 55°C for 12 mos. An undesirable toasted flavor was noted in these samples stored at this high temperature. Soy protein enriched taro rice stored at 38°C was found significantly different in flavor from those stored at lower temperatures.

However, the score was not as low as those at 55°C. Since no significant difference was found among samples stored at the 3 lower storage temperatures, extruded taro samples could be considered stable at normal tropical or subtropical storage temperatures.

The texture of these cooked, extruded taro products had a tendency to become firmer after 12 mos of storage at temperatures above 2°C (Table 2). Although there was no significant difference among taro rice and noodle stored at 2, 21, and 38°C, the average scores indicate that the higher the storage temperature, the firmer the cooked, extruded taro sample. Significantly firmer texture in taro rice and noodle were found in samples stored at 55°C. Taro macaroni was quite firm when fresh. Storage temperature and time did not have any significant effect on this product. However, the scores of taro macaroni also showed the same trend of becoming firmer due to higher storage temperature as observed in taro rice and noodle.

Table 3 shows that there were no significant changes of acceptability of taro rice as long as the samples were stored below 38°C. As for taro macaroni and noodle, storage temperatures did not have any significant effect on their acceptability. However, those stored at 55°C received a somewhat lower score. Taro macaroni was still rated higher than 4 in a scale of 7 after 12 mos of storage at 2, 21 and 38°C. These were the most acceptable ones among all the extruded taro products. Acceptability scores for taro noodle were the lowest among the extruded products probably due to the mushiness of taro noodles as compared to wheat noodles. Generally speaking, extruded taro products are quite stable and reasonably acceptable after long term storage at tropical and subtropical conditions.

Anthocyanin Pigments vs Brown Degraded Pigments. The decomposition of the anthocyanin pigments in stored extruded taro products is one of the characteristic measurement indicative of the stability of these taro products.

Table 4 illustrates that storage temperature substantially affected the anthocyanin pigments in all the extruded taro products. After 12 mos at 55°C, extruded taro samples changed from the original purplish brown color to a dark brown color. This is clearly shown by the low absorbance ratio at 55°C. However, the changes of absorbance ratio for samples stored below 38°C were not so drastic.

Different enrichment ingredients did not seem to affect the rate of anthocyanin decomposition during storage of these extruded taro samples except mung bean and soy-protein enriched rice which showed a greater drop in absorbance ratio in samples stored at 2°C abd 21°C. However, a similar result was not observed in mung bean enriched taro noodle stored at 2°C or 21°C. It was not easy by visual inspection to distinguish the samples stored for 12 mos at 2, 21 or 38°C.

Hunter Color Measurements. The Hunter Color Meter was used in determining the change of color in cooked taro samples during storage. Table 5 shows that the storage temperatures affected the color in the samples, especially at higher storage temperatures such as 55°C. Taro rice, with or without protein enrichment, showed gradual darkening with a decreasing L value. This darkening effect is consistent with the result of anthocyanin degradation during storage at high temperature. The "a" value increased with increasing storage temperature, especially at 55°C, which gave the sample a somewhat redder color than those stored at lower temperatures. High storage temperature also gave a more yellowish color in the sample with an indication of increasing "b" value. Different ingredients added to the products also influenced the change in sample color. Color of soy protein enriched taro rice changed considerably more than the plain taro rice in terms of L, "a'," "b" values. This was in agreement with visual observation of the products. The color change in extruded taro noodles and macaroni products followed the same trend.

Moisture Contents. The moisture changes were shown in extruded taro samples stored at 2, 21, 38 and 55°C. Although the initial moisture contents of taro rice, noodle, and macaroni were different, they reached a similar range after 12 mos of storage at each of the storage temperatures.

Protein enrichments did not change the moisture content of the samples. The higher the storage temperature, the lower the equilibrium moisture in the samples. About 1% moisture difference was observed between samples stored at 2 and 21°C but there was about 5% and 8% moisture drop in those sample stored at 38° and 55°C, respectively.

pH Changes. The results of pH measurements in extruded taro products after 12 mos of storage at 4 different temperatures are tabulated in Table 7. The pH of extruded plain taro samples stored below 38°C decreased only by 0.1-0.3 unit while mung bean enriched and soy protein enriched samples had a much greater drop in pH. Among those stored at 55°C, mung bean enriched taro rice had the largest pH change, from 6.21 to 5.02, while soy protein enriched rice was a close second in pH change. In general, the pH of these extruded taro products stored at or below 38°C were affected only slightly by storage temperature and very little by the ingredients. The pH of different forms of extruded products did not vary too much.

Texture Measurements. The textural changes in extruded taro products after being stored at 4 different temperatures for 12 mos are shown in Table 8. Texture was affected by both the storage temperature and ingredients. In most cases, samples stored at a higher temperature had a firmer texture than those stored at a low temperature after 12 mos except plain taro rice which had no significant difference at all 4 temperatures. Taro macaroni and the soy enriched samples followed a similar pattern. Taro noodle and mung bean enriched noodle became firmer when stored at 38°C and 55°C.

As ingredients seemed to play an important role in the texture of extruded samples, those enriched with mung bean and soy protein usually resulted in a firmer texture than plain taro products, except macaroni products. Among taro rice and taro noodle products, protein enrichments made the products firmer.

Protein Level. The protein levels in taro rice products stored at 4 temperatures for 12 mos were very stable. Taro rice enriched with 15% mung bean flour or soy protein were 50 to 100% higher in protein level than the plain taro products. These results indicate that the soy protein enriched taro rice was comparable to the commercial wheat products in protein content after a relatively long term storage at temperatures as high as 55°C.

Summary and Conclusions

A storage study of extruded taro products (taro rice, noodle, and macaroni) was conducted to determine the stability and acceptability of these products, some made with 15% mung bean flour or soy protein. Samples were stored for 12 mos at 2, 21, 38 and 55°C. Results show that significant flavor change was found in all the extruded taro samples stored at 55°C. Soy enriched taro rice stored at 38°C also showed significant flavor change. Firmness of the products was directly proportional to storage temperature, i.e., the higher the storage temperature the firmer the texture as observed from both the subjective and objective measurements except for plain taro rice. Acceptability of extruded taro products was not significantly affected by 12 mos of storage at

2, 21 and 38°C.

Anthocyanin pigments of the uncooked samples were found to degrade more at higher storage temperature, however, drastic changes were found only in samples stored at 55°C. Hunter color measurements of cooked samples stored at 55°C showed significant difference from those stored at lower temperatures. Moisture contents of extruded taro samples changed according to their storage temperatures but were not affected by different enrichments. At 55°C, samples dehydrated from the initial moisture of 8-12% to less than 4% after 12 months. Those stored at 38°C had equilibrium moisture contents of 5-6% while those stored at 2°C and 21°C increased slightly in their moisture contents. The pH values of taro samples decreased slightly during storage with mung bean enriched and soy protein enriched taro rice showing a larger pH drop than the other samples. Protein level of these taro samples was found stable during storage.

It can be concluded that extruded taro rice, noodle, and macaroni are stable products which can be stored for a period of at least 12 mos in tropical or subtropical conditions without significant changes in quality and acceptability.

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Table 1. Average scores on flavor of extruded taro products after storage at 4 different temperatures for 12 months[a]

Storage time (mos)	0	12			
Storage temp. (°C)	– –	2°	21°	38°	55°
Samples	– – – – *Flavor scores*[b] – – – –				
Taro rice, plain	5.3	4.9	4.6	4.4	2.3
with 15% mung bean flour	4.3	4.6	4.7	4.3	2.2
with 15% soy protein	5.3	5.2	4.8	4.0	2.0
Taro macaroni plain	5.3	4.7	4.1	4.4	2.7
with 15% soy protein	5.4	4.5	4.5	4.2	2.8
Taro noodle, plain	5.2	4.5	4.1	4.3	2.7
with 15% mung bean flour	5.2	4.8	4.4	4.5	2.8

[a] Each number is the average score of 12 panel judges in triplicate. Numbers jointly underlined indicate no significant differences between them. Otherwise they are significantly different at $p = 0.05$.

[b] Samples were scored on a hedonic scale of 7 where 7 = excellent and 1 = extremely poor.

Table 2. Average scores on texture of extruded taro products after storage at 4 different temperatures for 12 months[a]

Storage temp. (°C)	2°	21°	38°	55°
Samples		*Texture scores[b]*		
Taro rice, plain	3.0	2.8	3.4	3.8
with 15% mung bean flour	3.8	4.2	4.2	4.9
with 15% soy protein	3.3	3.7	4.1	4.8
Taro macaroni, plain	4.2	4.3	4.5	4.8
with 15% soy protein	4.3	4.4	4.5	4.6
Taro noodle, plain	2.3	2.5	2.8	4.2
with 15% mung bean flour	2.8	3.1	3.6	4.4

[a]Each number is the average score of 12 panel judges in triplicate. Numbers jointly underlined indicate no significant differences between them. Otherwise they are significantly different at $p = 0.05$.

[b]Samples were scored on a hedonic scale of 7 where 7 = excellent and 1 = extremely poor.

Table 3. Average scores on acceptability of extruded taro products after storage at 4 different temperatures for 12 months[a]

Storage time (mos)	0	12			
Storage temp. (^{o}C)	—	2^{o}	21^{o}	38^{o}	55^{o}
Samples	---- *Acceptability scores* [b] ----				
Taro rice, plain	4.5	4.1	3.9	3.8	2.6
with 15% mung bean flour	3.1	4.2	4.4	4.3	2.5
with 15% soy protein	4.3	4.4	4.2	3.7	2.3
Taro macaroni, plain	4.7	4.3	4.3	4.5	3.5
with 15% soy protein	4.4	4.1	4.2	4.0	3.1
Taro noodle, plain	3.4	3.3	3.2	3.8	3.0
with 15% mung bean flour	3.2	3.2	3.5	3.8	3.4

[a]Each number is the average score of 12 panel judges in triplicate. Numbers jointly underlined indicate no significant differences between them. Otherwise they are significantly different at $p = 0.05$.

[b]Samples were scored on a hedonic scale of 7 where 7 = excellent and 1 = extremely poor.

Table 4. Anthocyanin degradation in extruded taro products due to storage temperature and time[a]

Storage time (mos)	0	12			
Storage temp. (°C)	—	2°	21°	38°	55°
Samples	Absorbance Ration (520 nm/422 nm)				
Taro rice, plain	1.253	1.101	0.996	0.811	0.286
with 15% mung bean flour	1.217	0.905	0.849	0.714	0.273
with 15% soy protein	0.910	0.758	0.672	0.513	0.212
Taro macaroni, plain	1.573	1.471	1.369	1.202	0.433
with 15% soy protein	1.524	1.395	1.314	1.219	0.531
Taro noodle, plain	1.316	1.202	0.916	0.803	0.429
with 15% mung bean flour	1.305	1.314	1.176	1.086	0.470

[a]Each number is the average of duplicates.

Table 5. Color measurement of cooked extruded taro rice after 12-month storage at 4 different temperatures by Hunter Color Meter [a,b]

Storage temperature (°C)	L			a			b	b	
	T[c]	T + M[c]	T + S[c]	T	T + M	T + S	T	T + M	T + S
2°	50.5	51.2	51.5	5.0	5.0	4.7	3.7	6.1	7.9
20°	48.7	50.9	51.0	5.2	5.3	5.4	4.9	9.6	7.0
38°	48.1	50.7	37.7	5.7	5.5	4.8	12.2	8.1	6.4
55°	38.8	40.8	32.7	7.8	8.5	10.3	12.3	14.5	15.2

[a]Using standard grey plate of L = 31.8. a = 0.7, b = 0.3

[b]Values reported are averages of triplicate samples

[c]Taro = Taro flour only, T + M = Taro flour with 15% mung bean flour; and T + S = Taro flour with 15% soy protein

Table 6. Changes of pH in extruded taro products due to storage time and temperature[a]

Storage time (mos)	0	12			
Storage temp. (°C)	—	2°	21°	38°	55°
Samples			*Sample pH*		
Taro rice, plain	6.03	5.90	5.85	5.72	5.20
with 15% mung bean flour	6.21	5.70	5.44	5.31	5.02
with 15% soy protein	6.13	6.10	5.77	5.70	5.19
Taro macaroni, plain	6.27	6.11	6.06	5.98	5.43
with 15% soy protein	6.61	6.29	6.02	6.09	5.58
Taro noodle, plain	6.13	6.05	6.00	5.97	5.52
with 15% mung bean flour	6.34	6.01	5.82	6.04	5.62

[a]Values reported are averages of duplicate samples.

Table 7. Texture measurement of cooked extruded taro products after storage at 4 different temperatures for 12 months[a,b,c]

Storage time (mos)	0	12			
Storage temp. (°C)	--	2°	21°	38°	55°
Samples			*Work (kg-cm)*		
Taro rice, plain	778	377[a]	370[a]	462[a]	440[a]
with 15% mung bean flour	895	690[b]	825[b]	412[a]	870[b]
with 15% soy protein	795	570[c]	775[b]	780[b]	980[c]
Taro macaroni, plain	825	879	707	987	1352
with 15% soy protein	1155	965	677	830	1084
Taro noodle, plain	178	165[a]	125[a]	292[a]	500[a]
with 15% mung bean flour	298	320[b]	272[b]	722[b]	925[b]

[a]Averages of triplicate measurements.

[b]Effects of enrichment: superscript a vs. b: significant difference at p = 0.05 within a product form.

[c]Effects of storage temperature. Numbers jointly underlined indicate no significant difference, those not underlined are significantly different at p = 0.05 due to difference in storage temperature.

Table 8. Changes of protein level in taro rice during storage at 4 different temperatures for 12 months[a]

Extruded taro samples	Gross Protein, % (Dry weight basis) Storage temperature (°C)			
	2°	21°	38°	55°
Taro rice, plain	6.31	6.13	6.38	6.25
with 15% mung bean flour	9.13	9.25	9.50	9.25
with 15% soy protein	11.94	12.00	12.31	12.13

[a]Values reported are averages of duplicate samples. Values jointly underlined indicate no significant differences.