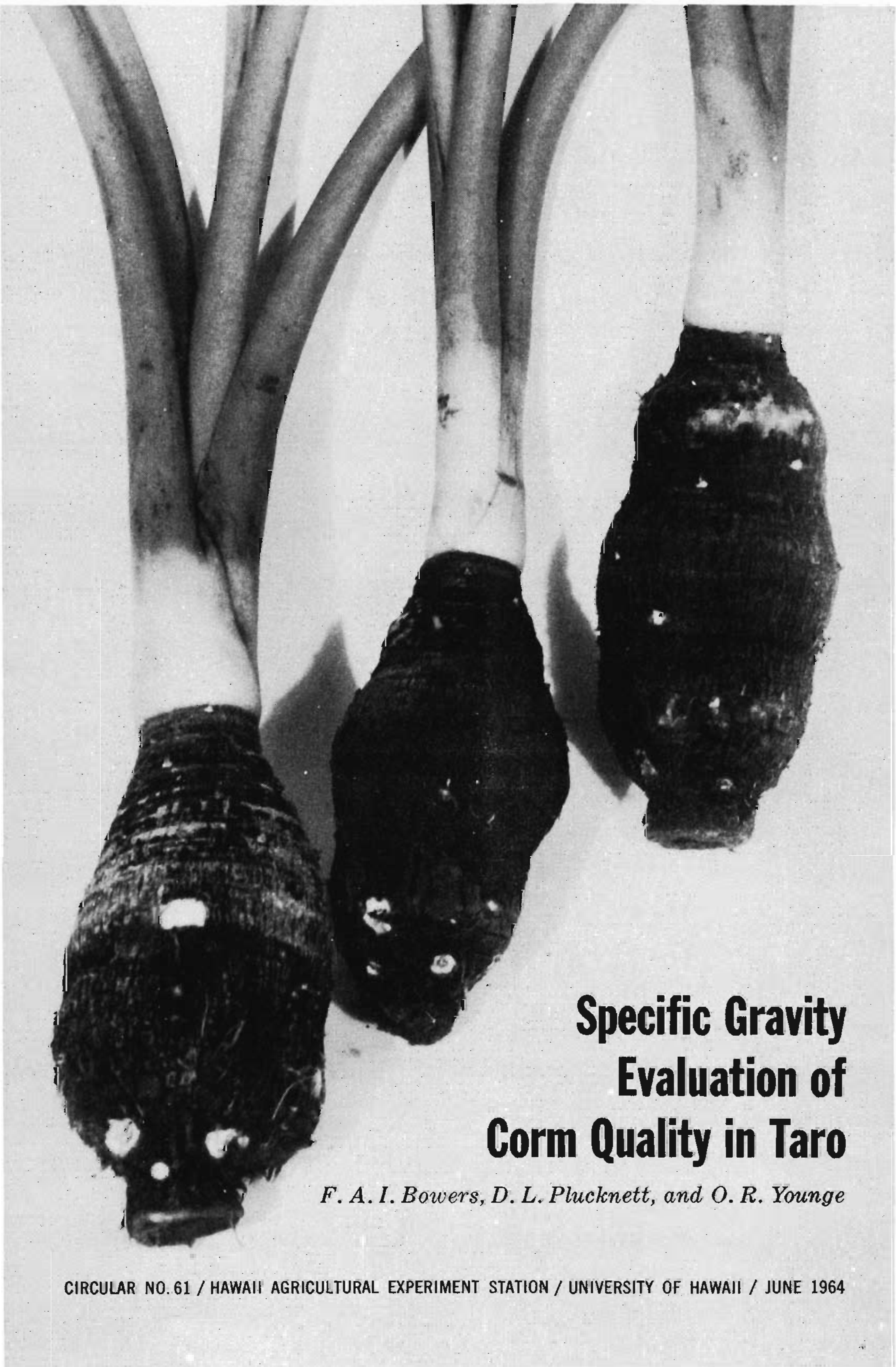

Specific Gravity Evaluation of Corm Quality in Taro

F. A. I. Bowers, D. L. Plucknett, and O. R. Younge

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INTRODUCTION

Taro varieties commonly planted in Hawaii are selected on the basis of their adaptability to different uses as human food. Heretofore, Hawaiian varieties have been evaluated chiefly for making poi. Assessing taro varieties on the basis of their adaptability for the production of certain dried taro products, especially flour, is also necessary if the taro industry is to expand into the production of taro flour for use in breads, baby foods, dietary foods, and similar products.

Certain physical characteristics of the taro corm have long been associated with the yield of poi. Growers commonly refer to "heavy," "light," and "loliloli" taro which range in apparent volume weight from heavy to light. "Heavy" taro is said to produce a high yield of poi, and "light" taro, a poor yield. Apparent specific gravity thus appears to offer a basis for separating taro corms into groups of similar potential yields. In this connection, Takahashi and Ripperton (*3*) found there was a highly significant linear regression coefficient of starch percentage with respect to specific gravity. In the potato industry, measurement of specific gravity of the tuber has been shown to be closely related to starch content, total solids, and mealiness, all of which are important to the industrial uses of potatoes (*1*). An attempt has been made in this report to correlate various apparent specific gravities of taro with quality and value of taro for different uses.

METHODS AND MATERIALS

A series of solutions of different specific gravities was made by adding the proper amounts of ethyl alcohol to water to obtain the specific gravity range 0.9–1.0, and by adding salt (NaCl) to water, to obtain the range above 1.0 (table 7).

A preliminary study of two wetland taro varieties was conducted using the following specific gravity solutions: 0.9–1.0, 1.0–1.05, 1.05–1.1, and 1.1–1.2. While in use, the solutions were checked frequently with a hydrometer. In this preliminary experiment, it was found that only a few of the corms showed less than 0.95 specific gravity, hence the use of alcohol solutions having specific gravities less than 1.0 could be eliminated. It was further shown that by using four salt solutions, the corms could be separated readily into five groups as follows:

Group	*Corm Specific Gravity*
A	less than 1.00
B	1.00 to 1.05
C	1.05 to 1.10
D	1.10 to 1.15
E	more than 1.15

Preliminary testing also disclosed that washing the corms to remove most of the adhering soil and removing the roots and extraneous material was sufficient to give reliable specific gravity readings. The cleaned corms were then classified by immersing them individually in the various specific gravity solutions until a solution was found in which the corm would barely submerge.

Corms from the separate specific gravity groups were weighed, cooked with steam in a pressure cooker at 15-pound pressure for 1 hour and 15 minutes, and then skinned and ground. The resulting "paiai"[1] was placed in pans and weighed.

Thereafter, the paiai was refrigerated at 36°–40° F until "setting" was complete. Setting time may be defined as the time necessary under refrigeration for paiai to solidify and to lose its sticky nature and pasty consistency, which then facilitates shredding. After setting, the materials were shredded in a Hobart shredder, weighed, placed in a tray dryer, and oven-dried to approximately 6 percent moisture. Moisture samples and final weights of the dried shreds were taken as needed for analysis. From these data the flour yield was then calculated for each sample and adjusted to the 6 percent water basis.

EXPERIMENTAL RESULTS

Oahu wetland taro varieties

Table 1 shows the data for two varieties of paddy or wetland taro which were processed in the initial experiments. Of considerable interest in these data is the shorter setting time for the higher specific gravity groups. It should be noted that setting time varied within samples of the same variety. Increased setting time appears to be associated with high water content in the wet shreds and with low specific gravity in the raw corms.

Since flour production is dependent on recovery of flour from the original raw material, it becomes obvious that recovery figures are most important. Highest flour recovery was consistently obtained from the higher specific gravity groups. Variety also appears to influence recovery figures as well as to influence time of setting of paiai. Thus the half-and-half mixture of Kaikea and Pikokea did not give a final recovery which was

[1] "Paiai" is defined as cooked, peeled, ground taro to which little or no water has been added. Poi is made by diluting paiai with water and allowing it to ferment (2).

an average of the original specific gravity groups for the varieties, and also the setting time of the blended sample was 30 hours contrasted with 24 hours for Kaikea and 52 hours for Pikokea.

It should be noted that paddy or wetland taro will outyield upland taro. However, in general, wetland taro has a lower specific gravity than upland taro, and also a lower percentage yield of poi and flour, as shown in tables 1 and 5.

Kona upland taro varieties

Ten taro varieties produced in a variety experiment under upland culture in Kona supplied corms for more detailed studies.

Table 2 and figure 1 give the weight distribution of corms for the different varieties in specific gravity groups. Striking differences in specific gravity groupings between varieties are evident. For example, corms of varieties Palaii and Lehua predominate in the heavier groups, while Palakea, Eleele naioea, and Chinese predominate in the lighter groups.

It is shown, also, that there is a marked difference in specific gravity and relative abundance between kalo (main corms) and oha (secondary or sucker corms). In general, the kalo are found in the lighter groups, and the oha in the heavier groups. Also, most varieties have kalo to oha ratios of about 50:50, whereas the variety Manakeokeo shows a ratio of 94:6, which may indicate a scarcity of hulis for replanting.[2]

Relationship of upland taro corm specific gravity to water content of raw taro and paiai, and to setting time of paiai

The time required for paiai to set is known to vary considerably among different lots of taro corms. The paiai from heavy corms is said to set faster than that from lighter corms. In table 3 and figure 2 are recorded the results on water content and paiai setting time for Kona upland taro, classified by specific gravity. The data show a definite relationship between specific gravity and setting time, with the D group (1.10–1.15) requiring an average of 2.6 days to set, while the A group (0.95–1.00) takes an average of 6.2 days to set. In this test the setting time was determined by visual inspection and was based on the time required for the milled, cooked, and peeled taro product to change from a viscous consistency to a firm solid when under refrigeration below 40° F. Preliminary tests showed that the addition of dried taro flour to slow setting samples greatly speeded the rate of setting and reduced setting time.

This observation might merit further investigation.

The data show, also, that variety is an important factor in setting time. Good poi varieties, such as Lehua and Palaii, required less than 3 days to set, while poorer varieties required more than 5 days.

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[2] Hulis are vegetative slips or cuttings taken from the top growth of the corm; therefore, the more corms, the more top growth.

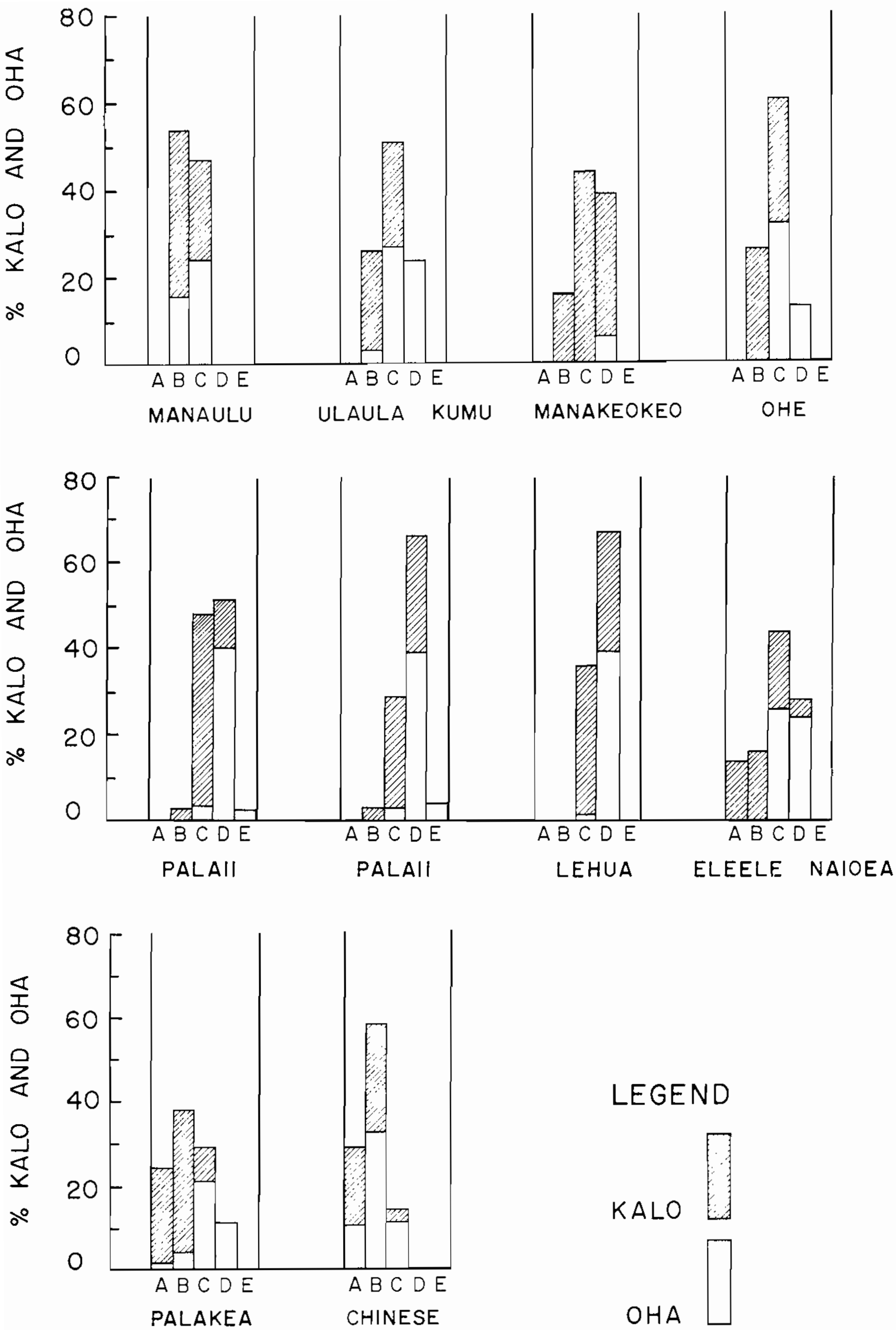

FIGURE 1. Weight distribution of oha and kalo taro corms in specific gravity groups (see table 7). Kalo corms tend to fall in the lower apparent specific gravity groups while oha corms tend to be heavier.

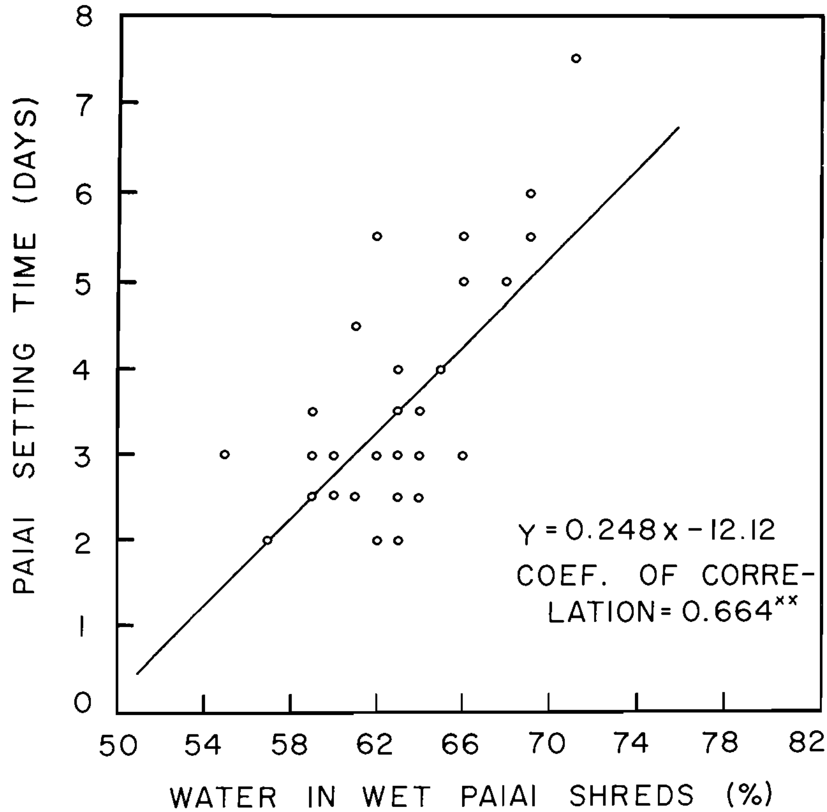

FIGURE 2. Relationship of water in wet paiai shreds to the time required for liquid paiai to set or solidify. The correlation is significant at the 0.01 percent probability level.

It is noteworthy also that in general the water content of the raw corm corresponds closely to that of the paiai, and that the water content varies inversely with the specific gravity of the raw corms and with the setting time of the paiai.

Relationship of taro corm specific gravity to yield of paiai

In processing taro for human consumption, the first usable product is paiai, which, when suitably diluted with water, becomes poi—the staple carbohydrate food of ancient Hawaii and Polynesia (*4*). A study was made on processed Kona taro in an attempt to establish the effect of specific gravity of the raw corm on the yield of paiai. The results are presented in table 4. The data show that the average yield of paiai from the different specific gravity groups is nearly the same.

Within various taro varieties, however, yields of paiai are shown to vary without regard to corm specific gravity. This lack of relationship

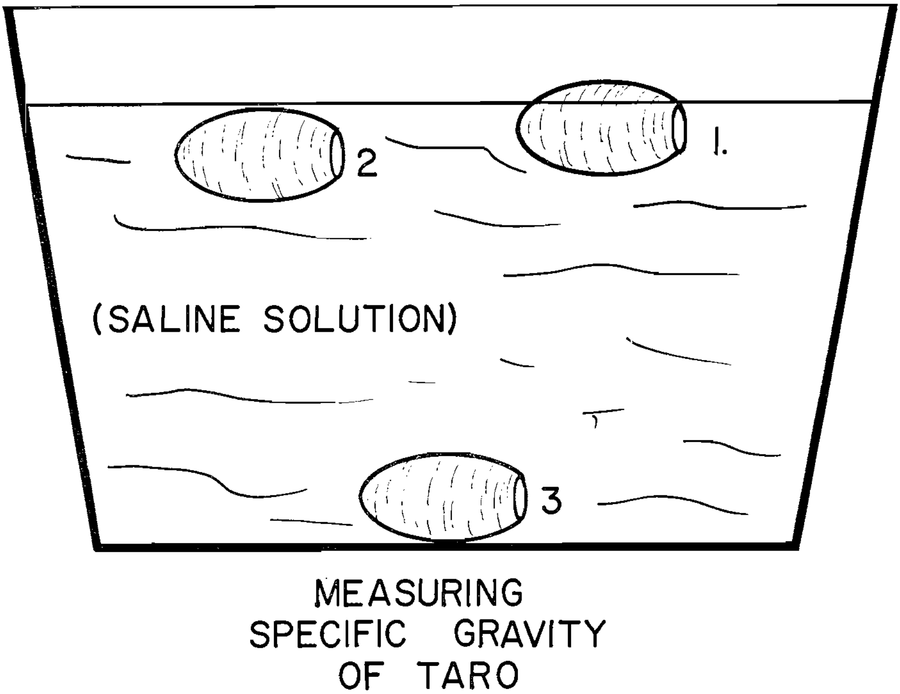

FIGURE 3. Segregation of taro corms into specific gravity classes is accomplished by using various test solutions of different salt concentration. Corm 1 floats with a portion above the surface, and is therefore of lower specific gravity than the test solution. Floaters may be tested in lower specific gravity solutions. Corm 2 floats fully submerged and is of the same specific gravity as the test solution. Corm 3, sinking to the bottom of the solution, is of higher specific gravity than the test solution. Sinkers may be tested in a higher specific gravity solution.

between corm specific gravity and paiai yield results from the fact that the ratio of water to dry matter remains essentially unchanged in going from raw taro to paiai. The loss in weight from raw taro to paiai consists of the peelings and the water in the outer covering of the corm. However, when the yields of paiai are compared on the basis of variety only, it is evident that yield of paiai is greatly influenced by taro variety. For example, varieties Makaopio and Lehua show high paiai recoveries, above 80 percent, as compared to low recoveries of 70 percent or less for the Chinese and Ulaula kumu varieties.

Relationship of taro corm specific gravity to yield of poi

Since the first salable product of processed taro is poi, which is usually sold on a 30 percent dry matter basis, the percentage recovery of poi from raw taro is of economic importance. The paiai yield of the Kona upland taro varieties was converted to poi of a constant 30 percent dry matter content, and the data grouped on the basis of apparent specific gravity as shown in table 5.

The data show that corms and taro varieties with the highest specific gravities produce the largest yields of poi. Those corms with low specific gravities have corresponding low yields of poi. This confirms what the taro industry has long recognized, that a relationship exists between the relative heaviness of taro corms and the corresponding yield of poi. It is evident, also, that corms with high dry matter content excel in yield of poi. However, corms of the same specific gravities but from different varieties do not produce the same quality of poi. From this it is evident that the starch factor in the dry matter of the corms must differ in chemical composition, and that this difference in composition in turn results in different poi qualities. Some taros, as a matter of fact, cannot gel and produce poi.

Relationship of corm specific gravity and yield of taro flour

The current investigation was initiated for the purpose of discovering the predictive value of corm specific gravity on the yield of taro flour. For the upland Kona taro varieties previously reported, the flour yield was obtained and the yield adjusted to a constant 6 percent water content, as shown in table 6 and figure 2.

A study of the data shows that, with minor exceptions, there is a definite increase in flour recovery with increase in corm specific gravity. Corms in group A (less than 1.00 specific gravity) gave flour yields much lower than yields for corms with specific gravities above 1.00.

Taro variety also appears to affect flour yield, the top poi varieties also being the top flour yielders. This is to be expected since both poi and flour yield tend to vary directly with the dry matter content of the corm. Because no data are available on the field yield of the taro corms, it is not possible to present the acre yields of flour for the various taro varieties reported here.

In all the experiments reported here, only first-class, clean, disease-free taro corms were used. For commercial taro, these desirable characteristics may be nearly absent, and therefore poi and flour yields may be lower than the experimental results reported.

SUMMARY

The relationships of taro corm specific gravity to yields of paiai, poi, and flour were investigated for several taro varieties grown under paddy or wetland and upland culture. Classification of the taro varieties was made into five specific gravity groups by means of salt water solutions of different concentrations. The clean corms were selectively immersed in the salt solutions, until barely submerged. The classified corms were steam-cooked under 15-pound pressure for 1.25 hours, peeled, ground into pulp, refrigerated at 4° C (40° F) until set, and then shredded. The shreds were oven-dried at 70° C (158° F), and then ground into flour.

Striking differences in specific gravity between varieties were observed. Corms of Palaii and Lehua were found in the heavier groups, while Palakea, Eleele naioea, and Chinese were found in the lighter groups. There was also a marked difference in specific gravity between kalo (main corms) and oha (secondary or sucker corms) of the same variety. In general, the kalo were found in the lighter groups, the oha in the heavier groups.

Setting time of paiai was shown to be shorter in the higher specific gravity groups. Increased setting time of the paiai is associated with high water content in the wet shreds and with low specific gravity of the corm.

Flour and poi yields were found to increase with specific gravity. Differences in flour and poi recovery between different varieties were also noted, the yields increasing with specific gravity and high dry matter content in the corm. The yields of paiai, however, were found to bear little direct relationship to corm specific gravity. Yields of paiai appear to vary directly with weight of the corm, and the ratio of water to dry matter content of the paiai remains about the same as in the raw corm.

On the basis of these findings, the determination of specific gravity appears to be a good method for evaluating corm quality in taro. Such a simple and cheap method can be used on the farm or at the factory as a reliable estimate of the total solids produced in a given variety. The specific gravity values may be used as a basis for estimating the marketable yields of poi and flour and hence as a basis also for pricing raw taro.

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APPENDIX

TABLE 1. Specific gravity of corms, time of setting, and percent recovery of taro flour from two wetland taro varieties from different sources

VARIETY	SPECIFIC GRAVITY OF CORMS	PAIAI SETTING TIME, HOURS	WATER IN PAIAI, PERCENT	FLOUR RECOVERY FROM RAW TARO, PERCENT
Kaikea	1.05–1.10	24	55.5	35.4
Kaikea	1.10–1.20	19	56.1	34.5
Pikokea	0.90–1.00	68	69.5	17.5
Pikokea	1.00–1.05	52	62.6	22.6
Pikokea	1.05–1.10	44	60.1	23.2
Mixture (50:50) Kaikea and Pikokea	1.05–1.10 1.00–1.05	30	57.3	26.1

TABLE 2. Specific gravity distribution of corms of different taro varieties under upland culture. (Data expressed as percent of total weight of taro corms.)

TARO VARIETY*	SPECIFIC GRAVITY GROUP A 0.95–1.00			B 1.00–1.05			C 1.05–1.10			D 1.10–1.15			E 1.15 +			TOTAL	
	Kalo†	Oha	Sub-total	Kalo	Oha	Sub-total	Kalo	Oha	Sub-total	Kalo	Oha	Sub-total	Kalo	Oha	Sub-total	Kalo	Oha
	Percent			*Percent*			*Percent*			*Percent*			*Percent*			*Percent*	
Lehua							33.3	1.8	35.1	25.7	39.3	65.0				59.0	41.0
Palaii				1.5	0.0	1.5	43.6	3.4	47.0	9.8	40.4	50.2	0.0	1.3	1.3	54.9	45.1
Palaii				2.1	0.0	2.1	25.6	2.2	27.8	27.2	38.9	66.1	0.0	4.0	4.0	54.9	45.1
Manakeokeo				16.9	0.0	16.9	44.7	0.0	44.7	32.2	6.2	38.4				93.8	6.2
Mana ulu				37.4	16.0	53.4	21.7	24.9	46.6							59.1	40.9
Palakea	21.4	1.8	23.2	34.1	3.8	37.9	7.6	20.5	28.1	0.0	10.9	10.9				63.0	37.0
Ohe				25.7	0.0	25.7	32.1	29.1	61.2	0.0	13.1	13.1				57.8	42.2
Eleele naioea	12.5	0.0	12.5	16.3	0.0	16.3	17.3	26.5	43.8	2.8	24.6	27.4				48.9	51.1
Chinese	18.2	10.3	28.5	25.5	32.4	57.9	2.8	10.8	13.6							46.5	53.5
Ulaula kumu				22.7	3.6	26.3	23.4	26.7	50.1	0.0	23.6	23.6				46.1	53.9
Distribution Percent	5.2	1.2	6.4	18.2	5.6	23.8	25.2	14.6	39.8	9.8	19.7	29.5	0.0	0.5	0.5	58.4	41.6

* Taro varieties are ranked in order of quality for poi.
† Kalo corms are produced from the original transplant slip or mother huli.
Oha are the corms developed from offshoots of the mother huli.

TABLE 3. Relationship of specific gravity, water content, and paiai setting time for various taro varieties

TARO VARIETY*	SPECIFIC GRAVITY GROUP															TOTAL		
	A 0.95–1.00			B 1.00–1.05			C 1.05–1.10			D 1.10–1.15			E 1.15 +					
	Water Content		Setting	Water Content		Setting	Water Content		Setting	Water Content		Setting	Water Content		Setting	Water Content		Setting
	Corm, Percent	Paiai, Percent	Time, Days	Corm, Percent	Paiai, Percent	Time, Days	Corm, Percent	Paiai, Percent	Time, Days	Corm, Percent	Paiai, Percent	Time, Days	Corm, Percent	Paiai, Percent	Time, Days	Corm, Percent	Paiai, Percent	Time, Days
Lehua							57	63	3.0	54	64	2.5				56	64	2.8
Palaii				62	59	3.5	58	62	3.0	56	63	2.5	54	63	2.0	58	62	2.8
Manakeokeo				73	68	5.0	65	63	4.0	60	55	3.0				66	62	4.0
Mana ulu				69	66	5.5	63	61	5.5							66	64	5.5
Palakea	65	66	5.0	61	65	4.0	58	60	3.0	56	59	2.5				60	63	3.6
Ohe				63	63	3.5	61	61	2.5	59	57	2.0				61	60	2.7
Eleele naioea	69	71	7.5	64	69	5.5	60	62	2.0	56	60	2.5				62	66	4.4
Haehae				66	66	3.0	63	63	2.0							64	64	2.5
Chinese	83	82	†	73	74	†	68	69	6.0							75	75	†
Ulaula kumu				64	61	4.5	60	59	3.0	53	59	2.5				59	60	3.3
Average	72	73	6.2	66	66	4.3	61	62	3.5	56	60	2.6				64	65	4.2

* Taro varieties are ranked in order of quality for poi.

† For the Chinese taro variety, the paiai for specific gravity groupings below 1.05 failed to set within 8 days.

Table 4. Yield of paiai by specific gravity groups of corms for various taro varieties under upland culture

TARO VARIETY*	SPECIFIC GRAVITY GROUP A 0.95–1.00			B 1.00–1.05			C 1.05–1.10			D 1.10–1.15			E 1.15 +			TOTAL YIELD		
	Corm, Lb.	Paiai, Lb.	Recovery, Percent	Corm, Lb.	Paiai, Lb.	Recovery, Percent	Corm, Lb.	Paiai, Lb.	Recovery, Percent	Corm, Lb.	Paiai, Lb.	Recovery, Percent	Corm, Lb.	Paiai, Lb.	Recovery, Percent	Corm, Lb.	Paiai, Lb.	Recovery, Percent
Makaopio				12.75	11.50	90.2	91.00	77.75	85.4	2.75	1.75	63.6				106.50	91.00	85.5
Lehua							83.75	73.75	88.0	155.00	121.75	78.5				238.75	195.50	81.9
Palaii				15.25	12.00	78.7	466.25	390.75	83.8	497.75	385.25	77.4	13.00	10.00	76.9	992.25	798.00	80.4
Manakeokeo				16.25	13.00	80.0	43.00	34.25	79.6	37.00	28.50	77.0				96.25	75.75	78.7
Mana ulu				55.25	43.00	77.8	48.25	37.25	77.2							103.50	80.25	77.5
Palakea	26.00	19.50	75.0	42.50	33.50	78.8	31.50	24.25	77.0	12.25	9.75	79.6				112.25	87.00	77.5
Palaii				19.00	14.75	77.6	258.00	201.75	78.2	611.75	470.25	76.9	37.25	30.00	80.5	926.00	716.75	77.4
Ohe				26.00	19.50	75.0	62.00	47.00	75.8	13.25	11.00	83.0				101.25	77.50	76.5
Eleele naioea	13.25	10.00	75.5	17.25	12.50	72.5	46.25	32.50	70.3	29.00	21.50	74.1				105.75	76.50	72.3
Haehae				32.00	22.75	71.1	58.00	42.25	72.8							90.00	65.00	72.2
Chinese	31.00	22.25	71.8	63.00	43.25	68.6	14.75	10.75	72.9							108.75	76.25	70.1
Ulaula kumu				27.50	19.25	70.0	52.50	35.50	67.6	24.75	17.25	69.7				104.75	72.00	68.7
Average			74.1			76.4			77.4			75.5			78.7			76.6

* Taro varieties are ranked in order of quality for poi.

TABLE 5. Yield of poi for various upland taro varieties and corm specific gravities (poi yield based on 30 percent dry matter)

TARO VARIETY*	SPECIFIC GRAVITY GROUP															TOTAL	
	A 0.95–1.00			B 1.00–1.05			C 1.05–1.10			D 1.10–1.15			E 1.15 +				
	Paiai Yield, Lb.	Paiai Water, Percent	Poi Yield, Percent	Paiai Yield, Lb.	Paiai Water, Percent	Poi Yield, Percent	Paiai Yield, Lb.	Paiai Water, Percent	Poi Yield, Percent	Paiai Yield, Lb.	Paiai Water, Percent	Poi Yield, Percent	Paiai Yield, Lb.	Paiai Water, Percent	Poi Yield, Percent	Dry Matter, Lb.	Poi (30% Dry Matter), Percent
Lehua							73.8	63	108.6	121.8	64	94.2				71.2	99.3
Palaii				12.0	59	106.0	390.8	62	99.0	385.2	63	94.8	10.0	63	99.3	268.9	90.3
Manakeokeo				13.0	68	85.4	34.2	63	98.2	28.5	55	115.4				29.6	102.6
Mana ulu				43.0	66	88.2	37.2	61	100.4							29.5	94.9
Palakea	19.5	66	85.0	33.5	65	91.9	24.2	60	105.1	9.8	59	108.7				32.1	95.2
Ohe				19.5	63	92.4	47.0	61	98.5	11.0	57	119.1				30.3	99.7
Eleele naioea	10.0	71	73.0	12.5	69	74.8	32.5	62	89.0	21.5	60	96.5				27.7	87.4
Haehae				22.8	66	80.5	42.2	63	89.8							23.4	86.5
Chinese	22.2	82	67.4	43.2	74	59.4	10.8	69	75.3							18.6	56.9
Ulaula kumu				19.2	61	91.0	35.5	59	92.3	17.2	59	95.2				29.1	92.6
Average		73			66			62			60						

* Taro varieties are ranked in order of quality for poi.

TABLE 6. Yield of flour for various upland taro varieties and corm specific gravities (flour yield based on 6 percent water content)

TARO VARIETY*	SPECIFIC GRAVITY GROUP															TOTAL		
	A 0.95–1.00			B 1.00–1.05			C 1.05–1.10			D 1.10–1.15			E 1.15 +					
	Corm Yield, Lb.	Flour Yield, Lb.	Flour Recovery, Percent	Corm Yield, Lb.	Flour Yield, Lb.	Flour Recovery, Percent	Corm Yield, Lb.	Flour Yield, Lb.	Flour Recovery, Percent	Corm Yield, Lb.	Flour Yield, Lb.	Flour Recovery, Percent	Corm Yield, Lb.	Flour Yield, Lb.	Flour Recovery, Percent	Corm Yield, Lb.	Flour Yield (6% Water), Lb.	Flour Recovery, Percent
Lehua							83.75	29.05	34.7	155.00	46.65	30.1				238.75	75.70	31.7
Palaii				15.25	5.23	34.3	466.25	157.88	33.9	497.75	151.61	30.5	13.00	3.94	30.3	992.25	318.66	32.1
Manakeokeo				16.25	4.42	27.2	43.00	13.46	31.3	37.00	13.64	36.9				96.25	31.52	32.7
Mana ulu				55.25	15.55	28.1	48.25	15.43	32.0							103.50	30.98	29.9
Palakea	26.00	7.05	27.1	42.50	12.47	29.3	31.50	10.30	32.7	12.25	4.27	34.9				112.25	34.09	30.4
Ohe				26.00	7.68	29.5	62.00	19.50	31.5	13.25	5.03	38.0				101.25	32.21	31.8
Eleele naioea	13.25	3.08	23.3	17.25	4.12	23.9	46.25	13.14	28.4	29.00	9.15	31.6				105.75	29.49	27.9
Haehae				32.00	8.25	25.8	58.00	16.61	28.6							90.00	24.86	27.6
Chinese	31.00	4.25	13.7	63.00	11.52	18.3	14.75	3.56	24.1							108.75	19.33	17.8
Ulaula kumu				27.50	7.97	29.0	52.50	15.49	29.5	24.75	7.50	30.3				104.75	30.96	29.6
Average			21.3			27.3			30.7			33.2						29.2

* Taro varieties are ranked in order of quality for poi.

TABLE 7. Specific gravity of aqueous sodium chloride solutions* (taro group and upper limit specific gravity)

TARO CORM GROUP	SPECIFIC GRAVITY	SODIUM CHLORIDE			
		In Solution, Percent	Grams/Liter	Pounds/Cubic Foot	Pounds/Gallon
A†	1.00	0.0	0	0	0
B	1.05	7.7	84	5.25	0.70
C	1.10	14.0	154	9.60	1.28
D	1.15	20.2	230	14.40	1.92
E	1.20	26.2	312	19.50	2.61

* To obtain a given volume of salt solution, dissolve the required quantity of salt in a smaller volume of water and add water to give the correct volume.

† In practice, any corm which floats with parts exposed above water may be included in group A.

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