HAWAII AGRICULTURAL EXPERIMENT STATION
HONOLULU, HAWAII
Under the joint supervision of the
UNITED STATES DEPARTMENT OF AGRICULTURE
AND THE UNIVERSITY OF HAWAII

BULLETIN No. 79

METHODS OF EVALUATING THE MACADAMIA NUT FOR COMMERCIAL USE AND THE VARIATION OCCURRING AMONG SEEDLING PLANTINGS IN HAWAII

By
J. C. RIPPERTON, Chemist
R. H. MOLTZAU, Principal Agricultural Aide
and
D. W. EDWARDS, Junior Chemist

Issued April 1938

UNITED STATES DEPARTMENT OF AGRICULTURE
OFFICE OF EXPERIMENT STATIONS

For sale by the Superintendent of Documents, Washington, D. C. - - - - Price 15 cents

HAWAII AGRICULTURAL EXPERIMENT STATION, HONOLULU

[Under the joint supervision of the Office of Experiment Stations, United States Department of Agriculture, and the University of Hawaii]

James T. Jardine, *Chief, Office of Experiment Stations.*
D. L. Crawford, *President, University of Hawaii.*

STATION STAFF

AS OF MAY 31, 1937

ADMINISTRATIVE

O. C. Magistad, Ph. D., *Director.*
H. K. Hee, *Junior Administrative Assistant.*

AGRONOMY:
- J. C. Ripperton, M. S., *Chemist.*
- J. M. Westgate, M. S., *Consultant in Tropical Agriculture.*
- L. D. Whitney, B. S., *Asst. Agronomist.*
- F. A. I. Bowers, B. S., *Prin. Agr. Aide.*
- A. W. Burt, N. D. D., *Prin. Agr. Aide.*
- E. Y. Hosaka, M. S., *Asst. Biol. Aide.*
- M. Takahashi, M. S., *Asst. in Agronomy.*

ANIMAL HUSBANDRY:
- L. A. Henke, M. S., *Animal Husbandman.*
- S. H. Work, Ph. D., *Assoc. Animal Husbandman.*
- G. W. H. Goo, B. S., *Asst. in Animal Husbandry.*
- C. Maruyama, B. S., *Farm Superintendent.*

BACTERIOLOGY, PATHOLOGY, AND HISTOLOGY:
- O. N. Allen, Ph. D., *Collaborator in Bacteriology.*
- G. K. Parris, Ph. D., *Assoc. Plant Pathologist.*

CHEMISTRY AND SOILS:
- O. C. Magistad, Ph. D., *Prin. Chemist.*
- E. M. Bilger, Ph. D., *Collaborator in Chemistry.*
- L. A. Dean, Ph. D., *Asst. Chemist.*
- D. W. Edwards, M. S., *Jr. Chemist.*
- R. R. Thompson, B. S., *Sci. Aide.*

FOODS AND NUTRITION:
- Carey D. Miller, M. S., *Assoc. Professor of Foods and Nutrition.*
- N. P. Larsen, M. D., *Collaborator.*
- Martha Potgieter, Ph. D., *Assoc. Chemist.*

HORTICULTURE:
- J. H. Beaumont, Ph. D., *Prin. Horticulturist.*
- G. W. Groff, M. S., *Collaborator in Horticulture.*
- W. W. Jones, Ph. D., *Asst. Physiologist.*
- J. E. Welch, M. S., *Jr. Olericulturist.*
- R. H. Moltzau, *Prin. Agr. Aide.*
- J. C. Thompson, B. S., *Prin. Sci. Aide.*
- W. B. Storey, B. S., *Biol. Aide.*

IRRIGATION:
- H. A. Wadsworth, B. S., *Irrigation Engineer and Soil Physicist.*

MARKETING:
- F. Okumura, B. A., *Marketing Assistant.*
- T. O. Frazier, B. A., *Sci. Aide.*
- J. Kaneshiro, B. S., *Jr. Sci. Aide.*

PARASITOLOGY AND ZOOLOGY:
- J. E. Alicata, Ph. D., *Parasitologist.*[1]
- C. J. Hamre, Ph. D., *Zoologist and Histologist.*
- H. G. Hansen, *District Agent.*[2]
- H. J. Spencer, B. A., *Asst. Biologist.*
- J. S. Caceres, *Collaborator.*[1]
- W. Jordan, *Sr. Sci. Aide.*
- W. Ishikawa, B. S., *Asst. Biol. Aide.*
- T. H. Hong, M. S., *Jr. Sci. Aide.*

POULTRY:
- C. M. Bice, B. S., *Poultry Husbandman.*
- B. A. Tower, M. S., *Asst. Poultry Husbandman.*
- F. L. Brown, *Asst. Agr. Aide.*

SUBSTATIONS:
- R. K. Pahau, B. S., *Superintendent Kona Substation.*
- R. A. Lyman, B. S., *Superintendent Haleakala Substation.*

---

[1] In cooperation with Territorial Board of Health.
[2] In cooperation with U. S. Department of Agriculture, Bureau of Biological Survey.

HAWAII AGRICULTURAL EXPERIMENT STATION
HONOLULU, HAWAII

Under the joint supervision of the
UNITED STATES DEPARTMENT OF AGRICULTURE
and the
UNIVERSITY OF HAWAII

BULLETIN No. 79

Washington, D. C. April 1938

METHODS OF EVALUATING THE MACADAMIA NUT FOR COMMERCIAL USE AND THE VARIATION OCCURRING AMONG SEEDLING PLANTINGS IN HAWAII

By J. C. Ripperton, *Chemist*, R. H. Moltzau, *Principal Agricultural Aide*, and D. W. Edwards, *Junior Chemist*

CONTENTS

INTRODUCTION

The macadamia has been grown in Hawaii as isolated trees or small orchards since the time of its introduction about 1892 (*7*).[1] Not until 1922 was an attempt made to grow the nut for commercial use. A stock company was formed and sizable plantings were made on two islands, Oahu and Hawaii. With this impetus other interests have made appreciable plantings in many locations on the several islands. The present plantings comprise about 800 acres containing about 60,000 trees, most of which are less than 15 years old. In 1931 a factory was built and machinery, specially developed for processing the macadamia as a roasted vacuum-packed article for the world trade, was installed.

At the time this investigation was begun no data existed as to the nature or extent of variation among macadamia seedlings. Plantings in Hawaii have consisted entirely of seedling trees, the seeds being taken from certain of the old trees of the Territory known to yield well and to produce nuts of good quality.

The same general situation appears to exist in Queensland and New South Wales, Australia, where the nut is indigenous. Most of the crop comes from the native "bush" and the largest bearing orchards

[1] Italic numbers in parentheses refer to Literature Cited, p. 23.

are but a few acres in size. Certain varieties have been named by nurserymen there, but, as far as can be ascertained, these are not based on extensive tests as to bearing, adaptability, or nut quality.

The investigations of the Hawaii Agricultural Experiment Station here reported consisted of a study of methods of evaluating the macadamia nut from the standpoint of its use as a commercial article in a shelled and roasted form rather than as a table nut in the unshelled form. Such an approach appears justified for a number of reasons. The present trend in the nut trade is strongly in the direction of extracted kernels. Even the thinnest shelled macadamias are difficult to crack with ordinary instruments owing to the smooth surface and tough fibrous nature of the shell, while the thick-shelled nuts offer serious obstacles to anything short of commercial machinery. Further, the flavor of the macadamia is greatly enhanced by proper roasting or oil cooking and salting. The station's investigations show that there is marked variation in kernel quality, and elimination of the inferior kernel is necessary to produce a uniform product. This is best accomplished in a commercial plant. Selection from this standpoint emphasizes the qualities of the extracted kernel which adapt it to processing as a roasted product rather than large size of nut or paper-thin shell, although these are not to be overlooked.

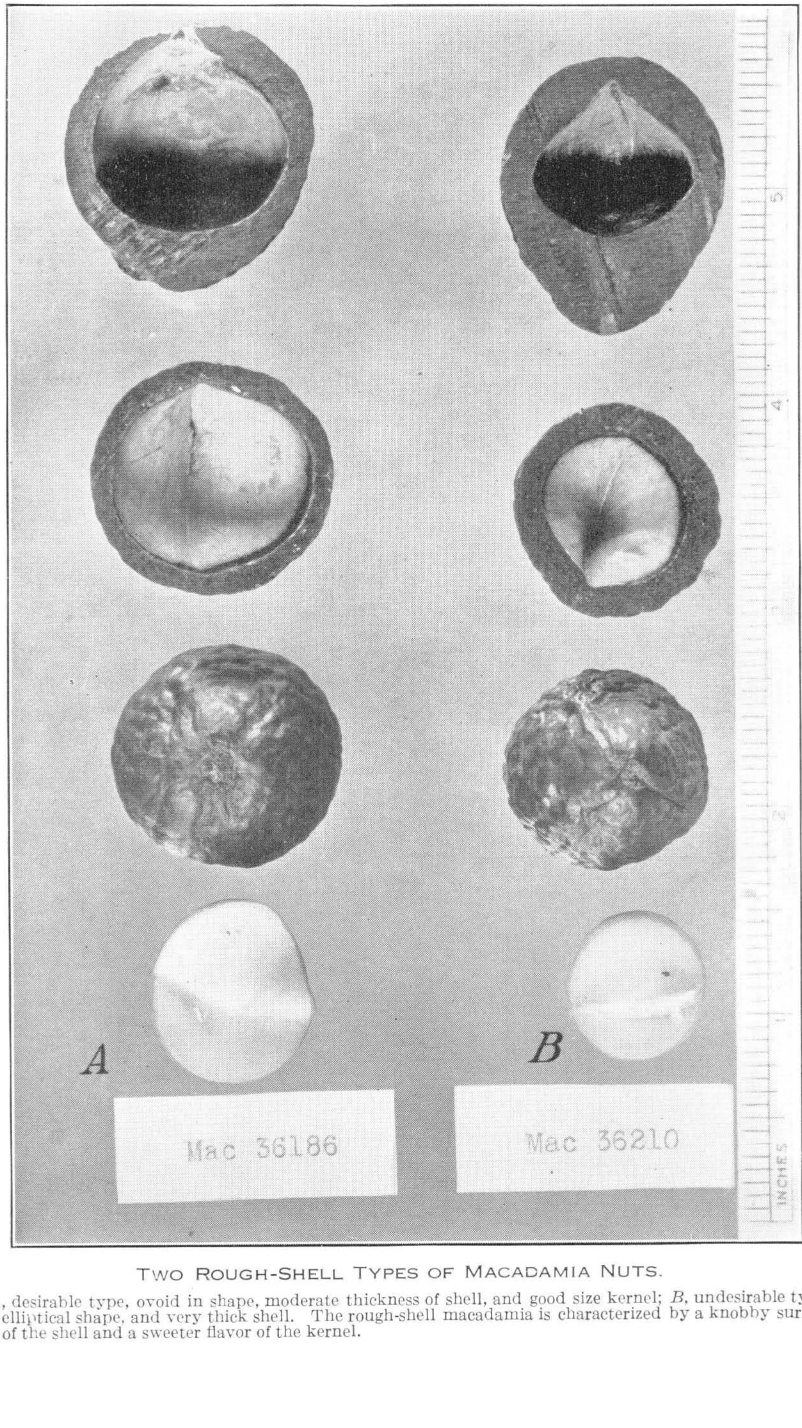
Using the methods developed by the station, nuts from the chief bearing orchards have been evaluated. Samples of nuts from individual trees have been tested for several crops. These show the extent to which seedling variation, climate, and type affect the nut characteristics. It is believed that these data, together with the methods of evaluation which have been developed, furnish a basis for an extensive study of the several thousand bearing seedling trees of the Territory, looking toward the selection of varieties for top working and further planting material.

THE ROUGH-SHELL AND SMOOTH-SHELL TYPES OF MACADAMIA NUTS

There are two distinct types of macadamias in Hawaii, the rough-shell type (*Macadamia ternifolia*) and the smooth-shell type (*M. ternifolia* var. *integrifolia*).[2] Presumably both types were brought in from Australia where the macadamia is indigenous. The present investigation shows that they have marked differences in both vegetative and nut characteristics (pls. 1, 2, and 3). Table 1 gives a comparison of the two.

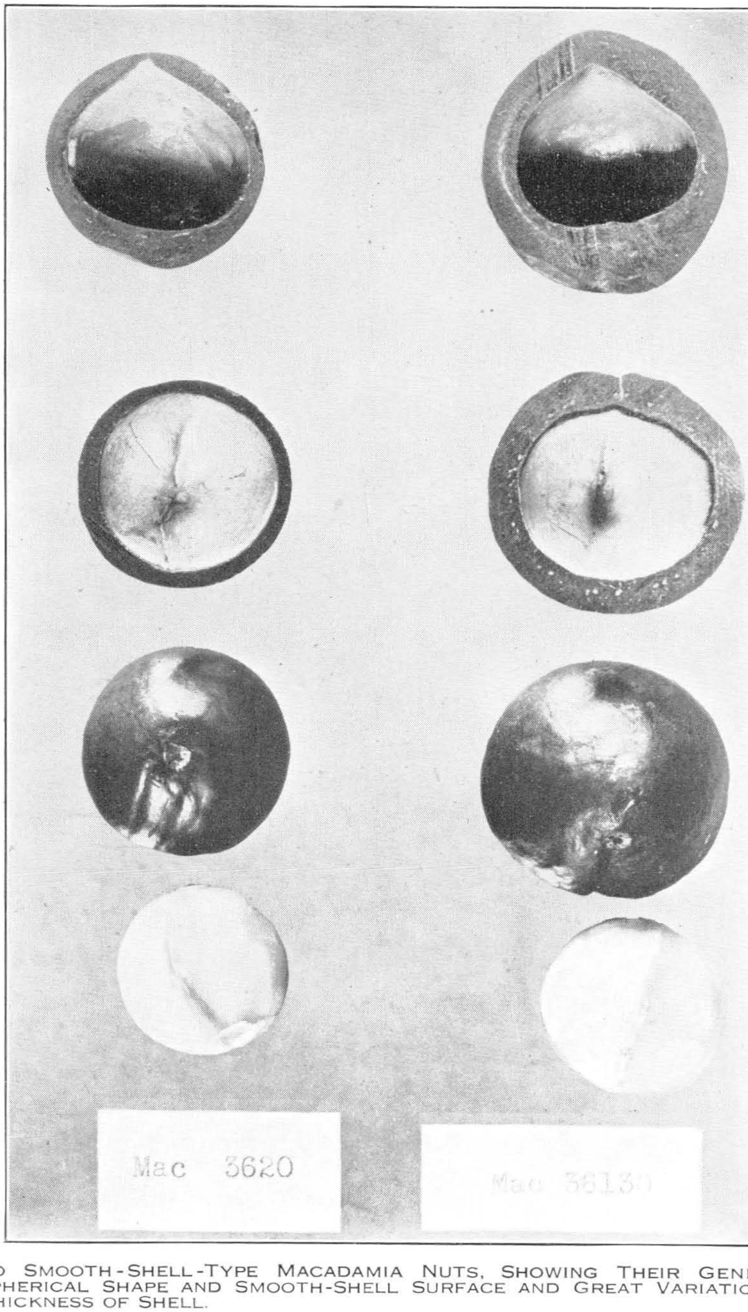
[2] There is some question as to whether the smooth-shell type should be classed as a separate species or as a variety of *Macadamia ternifolia*. For the present, and in this bulletin, the arbitrary term "type" is used instead of "species" or "variety."

A COMMERCIAL GROVE OF SMOOTH-SHELL-TYPE MACADAMIA NUTS, NUTRIDGE, OAHU. PHOTOGRAPHED 1935.



TWO ROUGH-SHELL TYPES OF MACADAMIA NUTS.

A, desirable type, ovoid in shape, moderate thickness of shell, and good size kernel; *B*, undesirable type, elliptical shape, and very thick shell. The rough-shell macadamia is characterized by a knobby surface of the shell and a sweeter flavor of the kernel.



TWO SMOOTH-SHELL-TYPE MACADAMIA NUTS, SHOWING THEIR GENERAL SPHERICAL SHAPE AND SMOOTH-SHELL SURFACE AND GREAT VARIATION IN THICKNESS OF SHELL.

The percentage of kernel in different trees ranges from 19 to 42. This type is generally considered superior to the rough-shell for a commercial roasted nut.

TABLE 1.—*Tree and nut characteristics of the rough-shell and smooth-shell types of macadamia nut*

Item	Rough-shell type	Smooth-shell type
Tree:		
Leaves	Excessively spiny; young leaves pink to red in color.	Somewhat spiny, young leaves usually green, rarely pink.
Bark	Light gray with many lenticels.	Dark gray with fewer lenticels.
Wood structure	Weak, resulting in much splitting of branches.	Fairly strong; much less splitting.
Susceptibility to insects	Attacked by leaf rollers, mealybugs, grasshoppers, aphids, and nut borer.	Damage negligible except for leaf rollers.
Age of initial bearing (seedlings).	3 to 4 years	4 to 6 years.
Unshelled nut:		
Shape	Ovoid to elliptical	Usually spherical.
Shell surface	Knobby	Smooth.
Shell texture	Tough, coarse, and fibrous	More brittle.
Raw kernel:		
Color	Darker kernel; grayish base	Clear, white kernel; usually light-colored base.
Shrinkage	Considerable	Usually small.
Texture	Firm; not easily chipped or bruised.	Tender; easily chipped and bruised.
Quality	Variable	Generally superior and more uniform.
Adhesion to shell	Generally loosens readily	Often adheres.
Roasted kernel:		
Color	Dark brown	Light golden.
Texture	Firm to hard	Tender, crisp.
Flavor	Pronounced, sweet, variable	Delicate, mild, uniform.

While considerable differences exist within each type both as to tree and to nut characteristics, there is no difficulty in differentiating between the two. From the standpoint of a roasted product the differences are pronounced. In the raw state, the smooth-shell kernel has a rather flat flavor and mealy texture while the rough-shell kernel has a somewhat pleasing sweetish flavor and firm texture. Upon roasting, the smooth-shell nut develops a light-brown color, crisp, tender texture, and a delightful mild nutty flavor, while the rough-shell kernel darkens quickly and develops a somewhat burned variable flavor and harder texture. Public preference for the smooth-shell roasted nut is by no means universal, but because of the greater uniformity in quality and more desirable field characteristics, the present trend is toward the smooth-shell type.

While most of the commercial plantings are of the smooth-shell type, there is a sufficiency of the rough-shell, particularly in the Kona district, to necessitate its inclusion in this investigation.

METHODS OF EVALUATING MACADAMIA NUTS [3]

INDIRECT METHODS OF DETERMINING THE OIL CONTENT

The oil content is of importance in evaluating a nut, not only because oil is the predominant constituent, but also because it serves as a criterion of other qualities. Chemical methods of determining the oil content of various products are laborious and time-consuming so that rapid indirect methods have been developed; for example, the refractive-index method of determining the oil content of flax (*2*) and avocados (*1*), and the Babcock method of estimating the oil in pecans (*5*). Specific gravity as an indirect means of determining variations in

[3] In the station investigation the nuts were brought to air-dry condition. This requires about 3 weeks in a dry, well-ventilated place. The air-dry moisture content of 3 to 4 percent permits cracking with a minimum of damage to the kernels.

chemical composition and quality has been used with a variety of products, for example, to show the starch content of potatoes (*4*), and the sugar content and maturity of prunes (*6*).

SPECIFIC GRAVITY

The macadamia kernel lends itself well to specific-gravity measurement, a single nut being of sufficient size to permit individual determination if desired.

The specific-gravity method, as finally perfected for the macadamia, was as follows: The kernel was suspended by forcing into it a fine steel wire of about 30 gage (Brown & Sharpe). To insure that there were no air spaces between the halves, the kernel was split and the halves were strung on the wire with the convex surface downward. The macadamia kernel is of such tender texture that the wire penetrates without difficulty and with a negligible rupturing of tissue. One end of the wire was bent into a hook and the nut was suspended on an ordinary analytical balance. It was weighed in air, and then immersed in ethyl alcohol of about 95 percent or any other convenient strength. Ethyl alcohol was found to be satisfactory for the purpose. Its specific gravity of 0.8092 (95 percent by volume at 25°/25° C.) is sufficiently less than that of the lightest macadamia kernel (about 0.965) to permit accurate determinations. Imbibition or interaction of nut and alcohol is negligible as judged by the fact that the weight of the kernel remains practically constant during the time required for weighing in alcohol. The volume of that portion of the steel wire which is submerged is a constant factor and too slight to be of consequence. The specific gravity of the alcohol solution was checked at intervals during the tests and frequent measurements of temperatures were made for intermediate corrections.

The kernel, after specific-gravity determination, was wiped dry and placed in a stream of air at 60° to 70° C. for about 1 hour to remove the last traces of liquid adhering. The oil was then determined by ether extraction in a Soxhlet apparatus for 24 hours. The procedure finally adopted was as follows: The kernel was placed on a 7-cm filter paper and shaved very fine with a sharp knife or razor blade. The filter paper and contents were placed in an alundum thimble and extracted in a Soxhlet apparatus overnight. The kernel was then ground in an agate mortar. Sufficient oil had been extracted so that the material could be ground to a fine powder. It was then replaced in the filter paper and alundum thimble and extraction continued for the remainder of the 24-hour period. The oil was dried to constant weight at 100°.

Specific-gravity determination has many desirable features as a laboratory method. It is very rapid and requires no special laboratory equipment. The determination of the specific gravity of a single kernel is often of great advantage. The kernel can subsequently be used for determination of oil, sugars, roasting qualities, or any other properties that it is desired to measure. Use of the entire kernel for ether-extract determination simplifies the procedure and increases its accuracy since exact sampling of the ground kernel is exceedingly difficult.

Table 2 gives the results of specific-gravity and ether-extract determinations on a series of 34 rough-shell and 60 smooth-shell kernels, the nuts being selected at random from commercial samples.

TABLE 2.—*Relation of specific gravity and oil content of macadamia nut kernels*

ROUGH-SHELL TYPE

Specific gravity	Oil content			Specific gravity	Oil content			Specific gravity	Oil content		
	Ether extract	Calculated from equation [1]	Deviation of calculated value from ether extract		Ether extract	Calculated from equation [1]	Deviation of calculated value from ether extract		Ether extract	Calculated from equation [1]	Deviation of calculated value from ether extract
	Percent	*Percent*	*Percent*		*Percent*	*Percent*	*Percent*		*Percent*	*Percent*	*Percent*
0. 9692	80. 23	80. 39	+0. 06	0. 9914	74. 89	75. 10	0. 21	1. 0463	61. 55	62. 01	0. 46
. 9709	78. 73	79. 99	1. 26	. 9938	75. 65	74. 53	−1. 12	1. 0464	62. 29	61. 99	−. 30
. 9764	79. 18	78. 67	−. 51	. 9947	73. 03	74. 31	1. 28	1. 0486	60. 35	59. 08	−1. 27
. 9783	76. 12	78. 22	2. 10	. 9969	74. 58	73. 79	−. 79	1. 0489	60. 00	61. 39	1. 39
. 9812	77. 63	77. 53	−. 10	1. 0013	73. 92	72. 74	−1. 18	1. 0498	61. 06	61. 18	. 12
. 9829	78. 71	77. 13	−1. 58	1. 0065	71. 02	71. 50	. 48	1. 0534	59. 81	60. 32	. 51
. 9838	78. 07	76. 91	−1. 16	1. 0115	70. 60	70. 31	−. 29	1. 0569	58. 92	59. 49	. 57
. 9847	76. 82	76. 70	−. 12	1. 0116	69. 86	70. 29	. 43	1. 0587	59. 11	59. 06	−. 05
. 9872	75. 55	76. 10	. 55	1. 0173	69. 54	68. 93	−. 61	1. 0622	58. 90	58. 22	−. 68
. 9873	76. 15	76. 08	−. 07	1. 0249	67. 72	67. 11	−. 61	1. 0837	54. 68	53. 10	−1. 58
. 9885	76. 87	75. 79	−1. 08	1. 0374	64. 18	64. 14	−. 04				
. 9910	74. 68	75. 20	. 52	1. 0414	62. 79	63. 18	. 39				

SMOOTH-SHELL TYPE

0. 9603	80. 36	80. 57	0. 21	0. 9870	74. 28	74. 89	0. 61	1. 0141	68. 48	69. 13	0. 65
. 9739	78. 07	77. 68	−. 39	. 9872	75. 24	74. 85	−. 39	1. 0144	68. 56	69. 07	. 51
. 9756	76. 88	77. 32	. 44	. 9873	75. 33	74. 83	−. 50	1. 0157	69. 07	68. 79	−. 28
. 9757	75. 79	77. 30	1. 51	. 9890	74. 67	74. 47	−. 20	1. 0198	66. 54	67. 92	1. 38
. 9758	78. 32	77. 27	−1. 05	. 9924	74. 57	73. 75	−. 82	1. 0221	68. 02	67. 43	−. 59
. 9765	79. 55	77. 12	−2. 43	. 9925	73. 95	73. 72	−. 23	1. 0227	67. 69	67. 30	−. 39
. 9791	76. 39	76. 57	. 18	. 9928	72. 34	73. 66	1. 34	1. 0237	66. 89	67. 09	. 20
. 9793	77. 93	76. 53	−1. 40	. 9959	73. 33	73. 00	−. 33	1. 0246	65. 92	66. 90	. 98
. 9801	74. 52	76. 36	1. 84	1. 0012	73. 20	71. 87	−1. 33	1. 0248	66. 72	66. 86	. 14
. 9802	77. 05	76. 34	−. 71	1. 0017	72. 60	71. 77	−. 83	1. 0290	66. 02	65. 97	−. 05
. 9805	74. 55	76. 28	1. 73	1. 0031	70. 35	71. 47	1. 12	1. 0301	66. 02	65. 73	−. 29
. 9806	76. 37	76. 25	−. 12	1. 0035	70. 87	71. 39	. 52	1. 0329	64. 85	65. 14	. 29
. 9816	76. 88	76. 04	−. 84	1. 0067	71. 51	70. 71	−. 80	1. 0355	64. 54	64. 58	. 04
. 9824	74. 39	75. 87	1. 48	1. 0068	71. 41	70. 68	−. 73	1. 0371	63. 80	64. 24	. 44
. 9828	75. 12	75. 79	. 67	1. 0068	70. 93	70. 68	−. 25	1. 0433	62. 57	62. 93	. 36
. 9834	74. 13	75. 66	1. 53	1. 0076	70. 53	70. 51	−. 02	1. 0475	63. 05	62. 03	−1. 02
. 9836	74. 60	75. 62	1. 02	1. 0080	70. 34	70. 43	. 09	1. 0535	61. 02	60. 76	−. 26
. 9839	76. 39	75. 55	−. 84	1. 0085	71. 42	70. 32	1. 10	1. 0539	59. 79	60. 67	. 88
. 9852	76. 01	75. 28	−. 73	1. 0107	70. 57	69. 86	−. 71	1. 0545	60. 50	60. 54	−. 06
. 9864	74. 19	75. 02	. 83	1. 0136	69. 49	69. 24	−. 25	1. 0740	56. 02	56. 40	. 38

[1] Equations (1) and (2) which are the best fitting curves of specific gravity/ether extract of the rough-shell and smooth-shell types, respectively (see below).

The coefficients of correlation of specific gravity and percent oil, calculated from data in table 2, are as follows:

$$\text{Smooth-shell type—}r = -0.979 \pm 0.005$$
$$\text{Rough-shell type—}r = -0.985 \pm 0.005$$

The degree of correlation is sufficiently high to permit the use of the specific gravity as a measure of the percentage of oil in macadamia kernels. In figure 1 the best fitting curves which relate specific gravity to percentage of oil are given for the two types. The equations for these graphs are as follows:

$$\text{(1) Smooth-shell type—}y = -212.57x + 284.70$$
$$\text{(2) Rough-shell type—}y = -238.35x + 311.40$$

where y=the percent of oil in the kernel and x=the specific gravity of the kernel.

REFRACTIVE INDEX

The method described by Coleman and Fellows (*2*) was used in determining the refractive index of macadamia kernels: A weighed amount of the material is ground in a mortar with a known amount of Halowax and the index of refraction of the liquid determined. By referring this value to a curve of the refractive indexes of varying proportions of Halowax and oil of the material being determined,

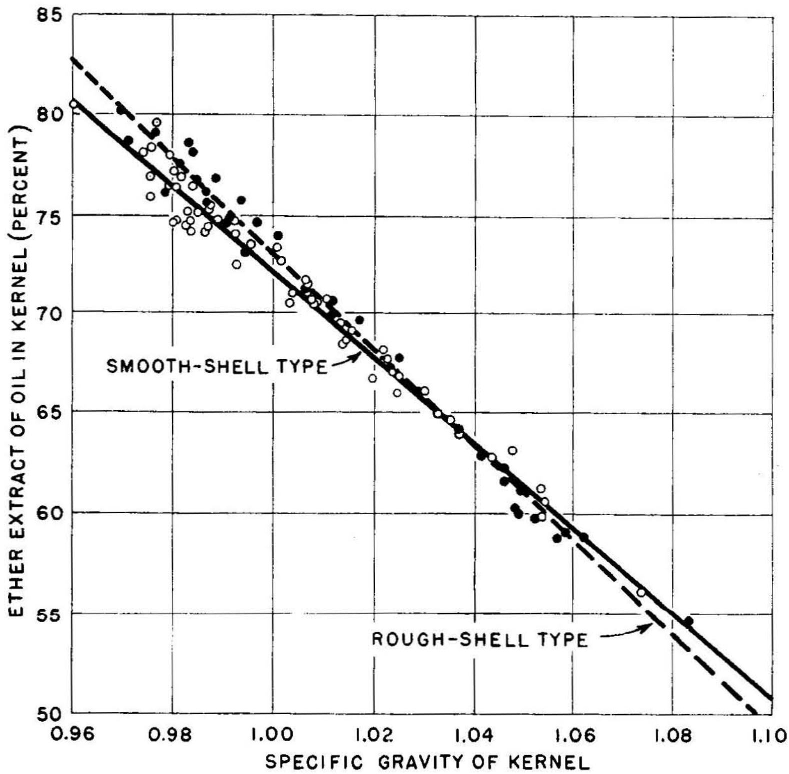


FIGURE 1.—Relation of specific gravity of macadamia kernels to ether extract.

the percent of oil in the Halowax is read off and the percent of oil in the original material calculated.

In the construction of this curve, oil was extracted from the smooth-shell type of macadamia kernels with ethyl ether. The oil was dried in vacuo at about 60° C. and filtered through filter paper. Varying amounts of this oil were added to constant amounts of Halowax for refractive-index determination. The Halowax was measured with a pipette, the same pipette being used for all determinations both of the oil and of the kernel. To 5 ml of Halowax weighing 6.06 ± 0.01 g weighed amounts of macadamia oil were added to provide a range of 0 to 29 percent of oil in the mixture. The refractive index was determined in a water-jacketed Abbe-Zeiss refractometer, the temperature being maintained at 27.5° C. This refractometer permitted direct reading to the third decimal place, the fourth place being estimated. The degree of accuracy is correspondingly less than that possible with an instrument of narrower range as used by Coleman and Fellows.

The values for index of refraction (N_D) are plotted against corresponding percents of oil in the Halowax-oil mixtures in figure 2. The equation for the best fitting curve is (3) $y=-497.11x+806.56$ where y=the percent oil in the Halowax-oil mixtures and $x=N_D$, the index of refraction.

The curve in the above equation does not hold for all values of x as proved by the fact that extrapolation of the equation to $x=1.4651$, the index of refraction of pure macadamia-kernel oil, gives values for y of 78 percent instead of 100 percent, its true value. Within the limits used, $x=1.57$ to 1.63, the true values of y follow the curve very closely.

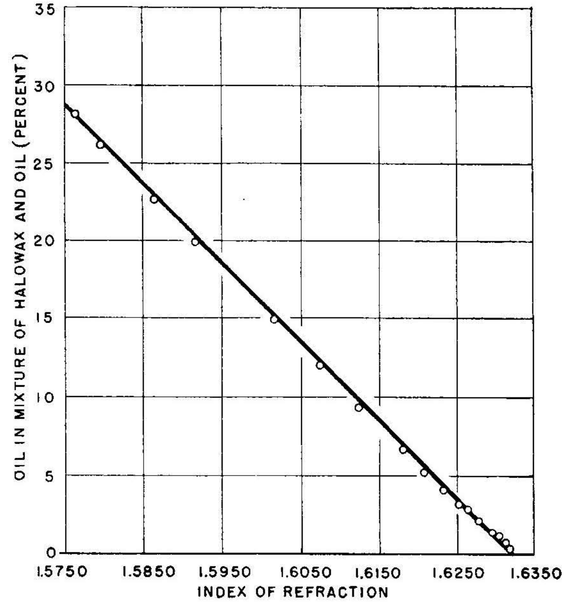


FIGURE 2.—Index of refraction of mixtures of macadamia nut oil and Halowax in varying proportions.

Using the relationship given in equation (3), the applicability of the refractive-index method to determination of the oil content of macadamia kernel was next studied. Kernels of the smooth-shell type were separated by specific gravity into 7 samples, each containing 12 to 15 kernels. Each sample was then finely chopped and thoroughly mixed. Ether-extract determinations were made as described under specific gravity. In determining the refractive index, 5 ml of Halowax were measured exactly as in the procedure described in the foregoing section and added to a weighed portion of the kernel in a small porcelain mortar. The mixture was then triturated with a pestle for about 10 minutes. A drop of liquid was withdrawn and the refractive index determined. Trituration was then continued until a constant reading resulted. For the final reading, a portion of the liquid was passed through filter paper. N_D determinations were made in triplicate and ether extract in duplicate. The results are given in table 3.

TABLE 3.—*Comparison of percent of oil by refractive index method with percent ether extract in macadamia kernels*

Weight of sample (grams)	Index of refraction at 27.5° C.	Proportion of oil in Halowax-oil mixture	Proportion of oil in kernel		
			Calculated from equation [1]	Ether extract	Deviation of calculated value from ether extract
		Percent	*Percent*	*Percent*	*Percent*
2.0473	1.5899	21.438	80.77		
2.0403	1.5902	21.325	80.55		
2.0022	1.5909	20.916	80.10	77.26	
Average			80.47	77.26	+3.21
2.1076	1.5899	21.428	78.45		
2.0464	1.5907	21.019	78.85	73.76	
2.0294	1.5912	20.763	78.29	74.84	
Average			78.53	74.30	+4.23
2.1728	1.5909	20.916	73.81		
2.2027	1.5902	21.274	74.38	71.28	
2.2405	1.5895	21.632	74.70	70.41	
Average			74.30	70.85	+3.45
2.0713	1.5919	20.405	75.04		
2.1184	1.5911	20.814	75.23	70.97	
2.2546	1.5893	21.734	74.68	71.27	
Average			74.98	71.12	+3.86
2.1647	1.5918	20.456	72.03		
2.0507	1.5930	19.843	73.19	68.78	
2.0273	1.5936	19.536	72.61	66.87	
Average			72.61	67.83	+4.78
2.0438	1.5958	18.411	66.95		
2.1495	1.5940	19.332	67.60	66.12	
2.3798	1.5908	20.968	67.60	66.51	
Average			67.38	66.32	+1.06
2.1546	1.5961	18.258	62.86		
2.2618	1.5949	18.871	62.35	61.23	
2.4903	1.5917	20.507	62.81	61.03	
Average			62.67	61.13	+1.54

[1] Equation (3) p. 7.

Table 3 shows the results by the refractometer method to be consistently higher than those by the ether-extract method, due probably to the solution of substances other than oil which affect the refractive index. The close agreement of triplicate results indicates that the refractive-index method of determining the oil content of macadamia nuts is essentially accurate if proper corrections of the curve are made. In fact, the differences between determinations are less in most instances than those by the ether-extract method.

For the present purpose the refractometer method has little to commend it as compared with the specific-gravity method. It is much more cumbersome and requires relatively expensive equipment. Moreover, with the specific-gravity method, the kernels are unaffected so that direct correlation may be had with other characteristics such as chemical composition, roasting qualities, and the like.

RELATION OF SPECIFIC GRAVITY TO TOTAL SUGARS

Figure 3 shows the relationship of specific gravity to total sugars in a series of smooth-shell kernels. There appears to be a definite positive correlation of the two where the percentages of sugar are high and the kernels are obviously immature.[4] The percentage of total sugars in normal, mature kernels varies from about 3 to 5 percent. Within this range there is little correlation.

RELATION OF SPECIFIC GRAVITY TO ROASTING QUALITIES

If kernels of varying specific gravities are roasted [5] there will be noted a marked relationship between specific gravity and the character

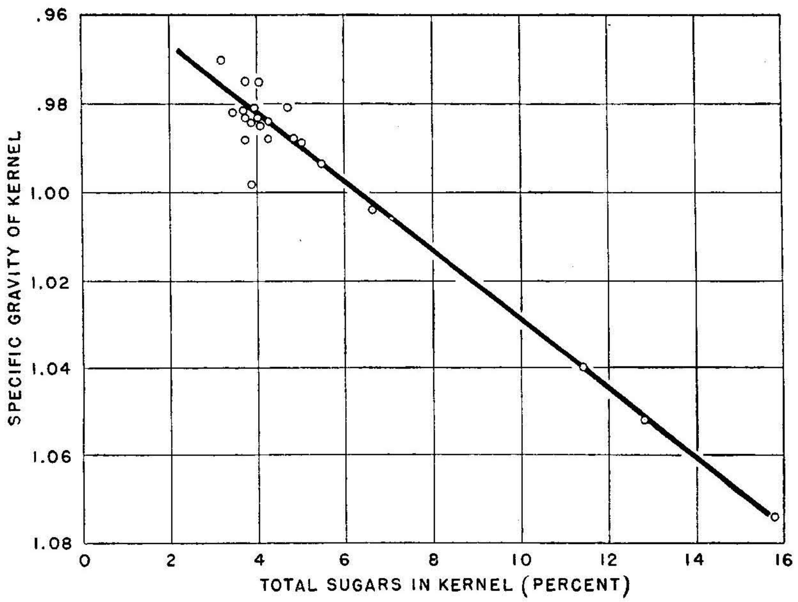


FIGURE 3.—Relation of total sugars in macadamia kernels to specific gravity.

of the roasted product. Kernels of high specific gravity acquire a dark-brown color, a strong scorched taste, and a hard or tough consistency. At the other extreme, the low specific-gravity kernels develop a light golden color, a mild nutty flavor, and a crisp texture. Specific gravity may thus be used as a basis for grouping of macadamia nuts according to their adaptability to a commercial roasted product.

A study was conducted to determine the relation of various specific-gravity groups of kernels to roasting qualities. Six water solutions were made up of the following specific gravities: 1.100, 1.050, 1.025, 1.000, 0.985, and 0.970. Sodium chloride was used to make the solutions of specific gravity greater than unity while ethyl alcohol was used for the solutions of less than unity. The increments in specific

[4] The term "mature" is used in this bulletin to mean kernels which are plump in appearance and show little shrinkage during curing. "Immature" kernels are defined as those which are shriveled and show considerable shrinkage during curing.

[5] The term "roasted" is used throughout this bulletin to indicate either oven roasting or oil cooking. Both methods were used. From the standpoint of evaluating kernel quality, the two are interchangeable.

gravity were made smaller in the solutions less than unity because of the greater concentration of kernels of normal composition in this narrow range.

To divide a lot of kernels into specific-gravity groups, the kernels are first placed in the solution of specific gravity 1.000 and stirred vigorously to eliminate air bubbles. The kernels which float are skimmed off and the adhering solution removed by centrifuging. They are then placed in the 0.985 solution. Those which sink obviously have a specific gravity between 1.000–0.985. In a similar manner the other separations are made so that a total of seven groups result from the six solutions, the heaviest group being that which sinks in the 1.100 solution, and the lightest that which floats on the 0.970 solution.

Table 4 shows the division into groups by this method and the relation of these groups to roasting qualities. The percentages of oil corresponding to these specific gravities were taken from the values given in figure 1.

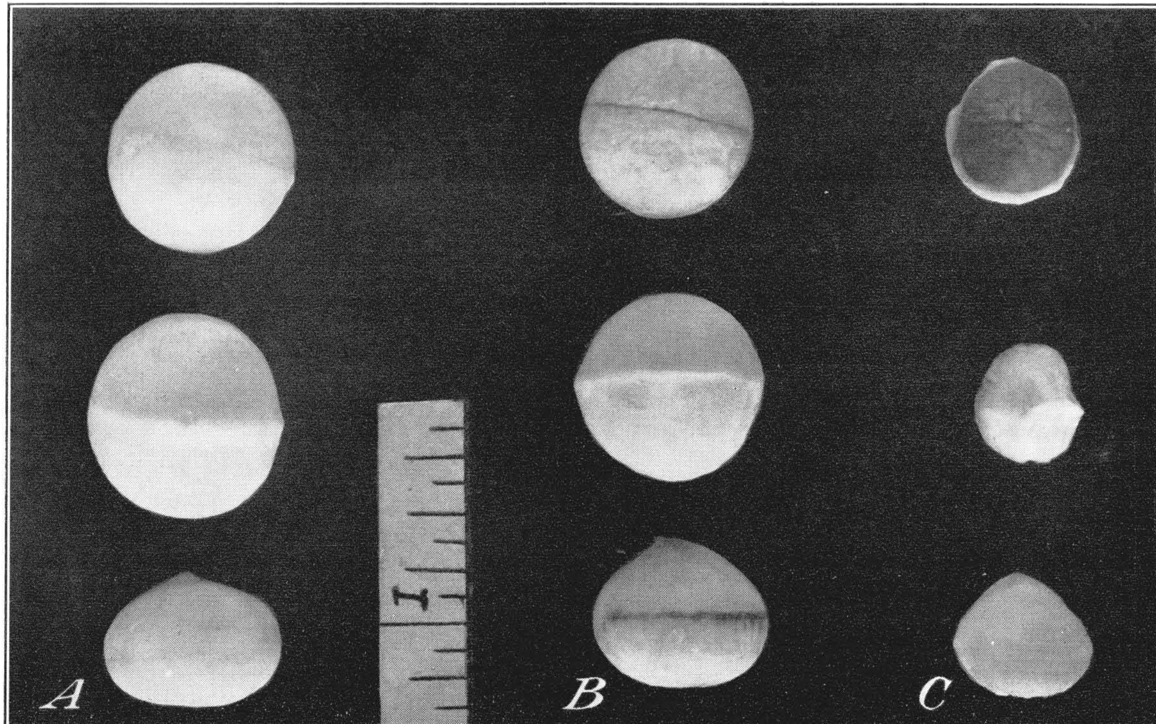
TABLE 4.—*Relation of specific gravity of smooth-shell-type kernels to roasting qualities*

Specific gravity	Proportion of oil in kernel	Appearance of raw kernel	Roasting qualities
	Percent		
>1.100	<50	Small size, shriveled base, hard or tough texture, off color.	Very dark color, unpleasant burnt flavor, hard texture.
1.100–1.050	50 –61.5	do	Do.
1.050–1.025	61.5–67	do	Do.
1.025–1.000	67 –72	Slight shriveling of base; variable in size and color.	Somewhat dark in color, tendency to off flavors and spongy texture. Saleable, but distinctly inferior to lighter nuts.
1.000–0.985	72 –75	Smooth base, plump, well filled, light color.	Light golden color, mild nutty flavor, crisp texture, excellent.
0.985–0.970	75 –78.5	do	Do.
<0.970	>78.5	do	Do.

Table 4 shows the best grades of kernels to be those of a specific gravity of 1.000 or less. The group 1.000–1.025 is variable in flavor and texture. Repeated tests of kernels of both types at different seasons of the year and from a number of localities have resulted in the placing of this group in a distinctly lower price class for use possibly in the baking or confectionery trade or as nut butter. Kernels with a specific gravity greater than 1.025 appear to have little value except for vegetable oil or nut butter. There is no perceptible difference in roasting qualities either as to flavor, texture, or color among the groups of specific gravity less than unity.

On this basis, all kernels of a specific gravity less than 1.000 are classed as grade 1; 1.000–1.025 as grade 2; and greater than 1.025 as culls. For practical purposes, it is thus possible to make all necessary separation with two solutions, namely 1.000 and 1.025 (pl. 4).

Ordinary tap water at normal room temperature is sufficiently pure for use in commercial grading. This abbreviated method is now being used commercially. It is more rapid and more accurate than hand separation of poor-grade kernels on the basis of the darker color and shriveled appearance after cooking. The expanded grading system is of value in the study of the differences in kernel quality in nuts from individual trees.



DIFFERENCE IN APPEARANCE OF MACADAMIA NUT KERNELS OF DIFFERENT SPECIFIC-GRAVITY GRADES.

A, Grade 1, specific gravity less than 1.000; *B*, grade 2, specific gravity 1.000 to 1.025; *C*, grade 3, specific gravity greater than 1.025. Upper row—base of kernels; middle row—top of kernels; lower row—side of kernels.

The rough-shell kernel conforms fairly well to the same division into grades. However, the differences in texture, color, and flavor between the rough and smooth types persist throughout all specific-gravity grades.

QUALITY-RATIO METHOD OF SCORING MACADAMIA NUTS

General standards have been set up for the grading of the more common commercial nuts. These have to do with the size and appearance of the unshelled nut, the relative wholeness of the kernels upon extraction from the shell, the color, size, and plumpness of the kernel, and its condition with respect to insect infestation (*3*, *8*). These standards have been set up largely from the standpoint of marketing the nut in the unshelled form.

The macadamia crop in Hawaii, coming as it does from seedlings, different types, numerous localities, and with great differences in cultural care, is subject to great fluctuation in nut characteristics. There is need for some method of evaluation of these qualities from the standpoint of both commercial value and selection.

The method of evaluating macadamias as finally developed is designed to determine the pounds of unshelled nuts required to produce 1 pound of grade 1 roasted kernel. This is designated "quality ratio." The following factors enter into this ratio:

SIZING OF UNSHELLED NUTS

Three screens with round holes 2.75, 2.45, and 2.10 cm in diameter, respectively, are used to divide the unshelled nuts. The four sizes of nuts are thus >2.75 cm, 2.75 to 2.45 cm, 2.45 to 2.10 cm, and <2.10 cm in diameter. All nuts of a diameter >2.10 cm are given full value and are termed sizable while those <2.10 cm are termed culls with no value. This division between sizable nuts and culls is based on commercial practice. Nuts of the cull size are irregular in size, shape, and quality. Discarding of cull nuts likewise serves to eliminate objectionably small sizes of kernels. No further account is taken of size of nut or of kernel in calculation of quality ratio.

PROPORTION OF KERNEL

The sizable nuts are cracked and the percent of kernels calculated.

GRADING OF KERNELS

The kernels of the sizable nuts are graded as in the regular specific-gravity method and the percent of kernels which are grade 1 determined. Grades 2 and 3 are given no value.

QUALITY RATIO

Calculation of the quality ratio is as follows:

$$\text{Quality ratio} = \frac{100}{\text{Percent sizable nuts} \times \text{percent kernel} \times \text{percent grade 1 kernels}}$$

An attempt was made to incorporate a color grading into the quality ratio. The normal macadamia kernel has a cream-colored base which roasts into an attractive golden brown. Certain kernels, apparently due to factors of climate and nutrition, as well as inheritance, have off-colored bases in the raw state. Others develop off-colors during roasting. Acceptable color standards for grading have not yet been agreed upon, therefore no account is taken of color in the quality ratio as used in this bulletin.

PURCHASE OF NUTS ON THE BASIS OF THEIR QUALITY RATIO

The quality ratio gives a single summation value for all the important qualities which affect the commercial value of the nut. By sub-

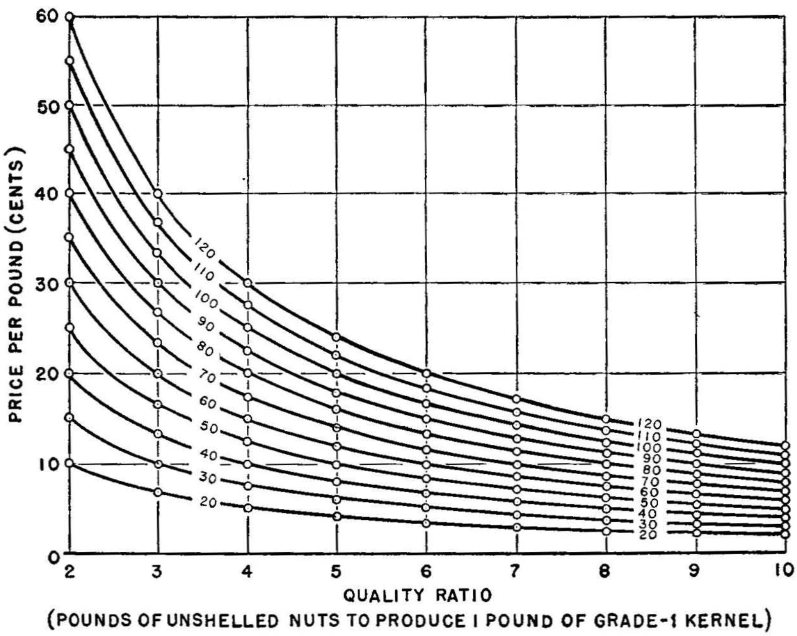


FIGURE 4.—Quality ratio as a means of determining the gross value of unshelled nuts. The curves represent the selling price of grade 1 kernels. Reading across to the ordinate gives the gross value of the unshelled nuts at prices of grade 1 kernels from 20 cents to $1.20 per pound. From this value must be subtracted the overhead to find the net value. (See below for an example of the use of this graph.)

stituting in the formula the values obtained from analyzing a sample of nuts it is possible for the purchaser of a lot of unshelled nuts to calculate the pounds of finished product he may expect. Figure 4 gives the gross value per pound of unshelled nuts of varying quality ratios for prices of the grade 1 kernel varying from 20 cents to $1.20 per pound.

An example of the method of using the graph is as follows:

Assume that the wholesale price [6] of grade 1 kernels is 80 cents per pound and a given lot of nuts has a quality ratio of 4.5. Reading across to the ordinate from the intersection of the 80 line and 4.5

[6] These values for price of kernels and for overhead are assumed. The market price and processing costs cannot be estimated with any degree of accuracy until production assumes larger proportions and methods of processing are better developed. The charging of overhead on the basis of unshelled nuts rather than on finished kernels seems justified in view of the fact that the factory operations of husking, curing, sizing, cracking, and grading are the same regardless of the quality ratio. The overhead saving in subsequent dehydration and roasting of the smaller quantities of nuts from the higher quality ratios would be negligible and would be offset by the enforced idleness of this part of the factory resulting from the poorer quality.

quality ratio gives a gross value of 17.8 cents per pound of unshelled nuts as received. This value can likewise be easily calculated by dividing the price per pound of kernel by the quality ratio; i. e., $80 \div 4.5 = 17.8$ cents. From this gross value must be subtracted overhead including profit per pound of unshelled nuts, the net being the price per pound to be paid to the grower. Thus with an overhead of 8 cents per pound, $17.8 - 8 = 9.8$ cents per pound net.

EVALUATING COMMERCIAL SAMPLES OF MACADAMIA NUTS BY THE QUALITY-RATIO METHOD

Two-pound samples of the various lots of macadamias received by a local company were scored by the quality-ratio method. Such samples are composites of all the bearing trees of the orchard in a number of localities and represent sufficiently large quantities of nuts to minimize to a great extent the effect of individual trees. They thus indicate seasonal trends, effect of climate, and average quality which may be expected from the seedling orchards of both smooth- and rough-shell types.

SMOOTH-SHELL TYPE

In the appendix (table 14) is given the results of scoring of individual shipments from five orchards of smooth-shell type, which are the principal bearing orchards of the Territory. Table 5 summarizes these results. In two locations, Waipahu and Nutridge, distinct seasonal trends appear. The results are subdivided into periods to make this apparent.

Table 5.—*Variation in quality of commercial shipments of smooth-shell nuts from 5 bearing macadamia orchards*

Period	Weight of nuts received	Proportion of total received	Sizing (diameter) of unshelled nuts				Proportion of kernel	Average weight per kernel	Percentage of kernels having a grade and specific gravity of—			Quality ratio	Hypothetical [1] net value per pound of unshelled nuts
			Large (>2.75 cm)	Medium (2.75–2.45 cm)	Small (2.45–2.10 cm)	Culls (<2.10 cm)			Grade 1 (<1.000)	Grade 2 (1.000–1.025)	Grade 3 (>1.025)		
	Pounds	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Grams*	*Percent*	*Percent*	*Percent*		*Cents*
WAIPAHU, OAHU													
July 26–Sept. 13, 1935	736	12.9	3.9	32.9	53.5	9.7	28.7	1.95	71.8	17.0	11.2	5.69	6.0
Sept. 13–Dec. 9, 1935	1,945	34.2	3.7	37.3	55.0	4.0	29.3	2.17	95.6	2.9	1.5	3.75	13.3
Dec. 9, 1935–Jan. 24, 1936	3,004	52.9	8.2	34.7	51.2	5.9	26.2	2.02	96.3	2.4	1.3	4.22	11.0
Total or average	5,685		5.8	35.0	52.9	6.2	27.7	2.10	90.0	6.2	3.8	4.27	
NUTRIDGE, OAHU													
July 2–Sept. 3, 1935	3,336	17.9	13.8	23.9	54.5	7.8	29.7	2.11	78.9	12.7	8.4	4.71	9.3
Sept. 3, 1935–Jan. 27, 1936	15,275	82.1	8.4	33.4	52.1	6.1	30.2	2.21	95.4	3.2	1.4	3.72	13.6
Total or average	18,611		9.8	32.0	51.8	6.2	30.0	2.19	90.4	6.0	3.6	3.92	
KEAUHOU, HAWAII													
May 5, 1935–Jan. 30, 1936	8,975		19.4	45.2	32.7	2.7	25.8	2.09	78.9	13.5	7.6	5.11	7.7
HAIKU, MAUI													
Aug. 13–Dec. 25, 1935	1,612		10.8	44.2	41.2	3.8	28.6	2.23	94.9	2.4	2.7	3.90	12.5
KALAHEO, KAUAI													
Oct. 7, 1935–Jan. 7, 1936	1,694		15.0	28.7	48.3	8.7	29.5	2.01	93.3	4.8	1.9	4.07	11.7

[1] Assuming the hypothetical values of 80 cents per pound kernel and 8 cents per pound overhead

The season's average of the various localities shows some marked differences, particularly with regard to the quality of kernels. In this respect Keauhou, Hawaii, is much lower in grade 1 kernels than the others. It is likewise lower in proportion of kernel. In percent of sizing culls and average weight per kernel, all locations are similar and acceptable.

At Waipahu, during the initial period the quality of kernels was poor but improved rapidly. The quality ratio reached its lowest value of 3.75 during September and October. In the subsequent period the kernel quality increased slightly but the quality ratio dropped due to a decrease in the proportion of kernel. This phenomenon has been noted in other instances and is probably significant. Poor kernel quality during the early part of the season is evident at Nutridge, but there is no appreciable decrease in quality ratio during the last of the season.

There is no marked seasonal trend in the grading of the nuts from the other localities although in the case of Haiku, Maui, and Kalaheo, Kauai, the shipments were limited in amount and number, and it is possible that the early harvest of poorer nuts was not sold. With respect to Keauhou, however, the harvesting period extended from May 1935 through January 1936. During this entire time the quality ratio remained fairly constant.

The importance to the commercial buyer of these differences in quality ratio of nuts from different sources and at different seasons of the year is apparent in the last column of table 5. Obviously these figures would change with the assumed price and overhead, but they do bring out the important fact that variation in quality is appreciable in commercial samples. An illustration of a single shipment which was below par is Keauhou, sample No. 642 (table 14) with a quality ratio of 6.45. This shipment of 695 pounds on the basis used above was worth only 4.4 cents per pound. New trees coming into bearing, hard winds, drought, excessive cloudy weather, nutritional factors, all may be contributing factors in such a sudden change in quality. Purchase of nuts on the basis of their quality ratio would mean a higher price for high-quality nuts and should act as a stimulus to growers to improve quality through top working and better cultural practices.

ROUGH-SHELL TYPE

Samples of rough-shell nuts were received from the Macadamia Nut Cooperative Marketing Association, located at Kailua, Hawaii. The association hand-cracked the crop and divided the kernels by specific gravity into grades. Composite samples of the hand-cracked kernels of each shipment were forwarded to the station. Results of scoring these commercial shipments are given in table 6.

TABLE 6.—*Scoring of factory shipments of rough-shell-type macadamia nuts from Kona, Hawaii, 1935–36*

Shipment No.	Date received at Honolulu	Weight of unshelled nuts	Proportion of kernel	Percentage of kernels having a grade and specific gravity of—			Quality ratio	Grade 1 kernels
				Grade 1 (<1.000)	Grade 2 (1.000–1.025)	Grade 3 (>1.025)		
		Pounds	*Percent*	*Percent*	*Percent*	*Percent*		*Pounds*
1	Dec. 1935	136	21.7	27.9	38.2	33.9	16.54	8.2
2	Feb. 17, 1936		24.0	44.5	40.1	15.4	9.35	
3	Mar. 7, 1936	295	26.4	53.4	33.7	12.9	7.09	41.7
4	Mar. 17, 1936	808	25.5	70.8	23.5	5.7	5.54	146.1
5	Mar. 26, 1936	1,228	24.6	65.5	23.9	10.6	6.22	197.4
6	May 7, 1936	695	23.5	79.9	16.2	3.9	5.32	130.6
7	May 25, 1936	418	27.0	84.9	12.7	2.4	4.35	97.0

Table 6 shows an extremely poor quality of kernels in the early part of the season, with only 27.9 percent grade 1. Improvement in quality is rapid as the season advances, the last shipment having the highest value of 84.9 percent. The bulk of the crop was contained in the fourth, fifth, and sixth shipments, in which the proportion of grade 1 kernels was 65.5 to 79.9 percent. This is much below the standard of the smooth-shell types. As has been noted, the rough-shell type has other undesirable features as a commercial nut, such as poor color, variable flavor, and undesirable tree characteristics.

EVALUATION OF NUTS FROM DIFFERENT SEEDLING TREES FROM DIFFERENT LOCALITIES

The bearing trees of macadamia are made up of miscellaneous old trees found in many locations throughout the Territory and a number of commercial orchards, many of which are just coming into bearing. All trees are seedlings. The origin of the seed used in the various plantings is seldom known even in the younger commercial orchards. It requires only casual inspection to note the great variations among the trees in any one orchard. These variations are manifest not only in vegetative characteristics but also in fruiting habits, such as total yields, distribution of the harvest throughout the year, and the various factors of nut quality.

VARIABLE FACTORS

DISTRIBUTION OF THE CROP THROUGHOUT THE BEARING SEASON

Nuts were collected throughout the bearing season from a series of 12 seedling trees at Waipahu, Oahu, to determine the variations in the drop of nuts throughout the year. The results are given in table 7.

TABLE 7.—*Variations in distribution of the crop of husked nuts throughout the bearing season of 12 8-year-old seedling trees of the smooth-shell type, Waipahu, Oahu, 1930–31 crop*

Tree No.	1930						1931					Total yield
	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	
	Lb.	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*
1	17.9	10.8	23.7	6.5	1.3	0.7	0.4	1.0	1.3	0.9	0.6	65.1
2	.4	1.1	8.9	8.3	5.5	6.2	9.8	3.9	2.3	1.0	.7	48.1
3	3.6	17.0	12.8	12.0	2.8	2.8	2.8	2.0	1.6	-----	-----	57.4
4	5.3	6.6	10.9	11.5	10.1	5.2	4.1	1.1	1.1	-----	-----	55.9
5	-----	.3	1.0	5.3	7.4	17.8	6.4	1.8	3.1	-----	-----	43.1
6	2.6	2.2	13.5	11.0	9.5	1.6	1.3	.7	1.4	-----	-----	43.8
7	.3	1.2	5.8	16.0	4.3	5.6	8.3	6.3	3.8	1.3	.6	53.5
8	.6	.3	2.9	31.5	5.6	8.9	3.5	4.3	4.5	3.8	.7	66.6
9	.6	2.6	11.3	12.8	4.8	2.7	1.0	.4	-----	-----	-----	36.2
10	3.1	17.1	14.5	11.5	6.3	.4	1.7	-----	-----	-----	-----	54.6
11	8.2	6.4	25.7	10.5	1.1	.2	-----	-----	-----	-----	-----	52.1
12	22.9	6.7	12.9	.6	3.1	.6	-----	.8	-----	-----	-----	47.6

In this group of trees there are early bearers (Nos. 1 and 12) and late bearers (No. 5). There are those which bear the bulk of their crop in 2 or 3 months (No. 11) and others which bear nearly the year around (Nos. 7 and 8). The variation in bearing habits of the macadamia gives a wide range of harvest possibilities which commercialized interests may use to base further plantings of selected trees to conform, in turn, with local labor and processing conditions.

TYPES OF DISTRIBUTION OF KERNELS INTO SPECIFIC-GRAVITY GRADES

Grading of many lots of macadamia nuts taken systematically from specific locations or individual trees has shown different and characteristic types of distribution. Table 8 shows typical examples.

TABLE 8.—*Characteristic types of distribution into specific-gravity grades of nuts from seedling trees*

Distribution type and tree	Percentage of nuts in the group having a specific gravity of—					
	Group 1 (<0.970)	Group 2 (0.970–0.985)	Group 3 (0.985–1.000)	Group 4 (1.000–1.025)	Group 5 (1.025–1.050)	Group 6 (>1.050)
Smooth shell:	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
a	41	58	0	1	0	0
b [1]	13	25	18	18	10	16
c	23	39	31	0	1	6
d	20	21	18	1	0	40
Rough shell:						
e	16	37	22	21	3	1
f	3	0	6	20	20	51

[1] Same tree as "a" the following year.

In considering table 8, it is not possible to separate out and evaluate the various factors of type, locality, condition of tree, size of crop, and the like which might affect grade of kernels. The differences in specific-gravity distribution between crops from the same tree in successive years are illustrated in types a and b. In 1930–31, type a, the yield was heavy and practically the entire crop was in groups 1 and 2. In 1931–32, type b, the crop was distributed fairly evenly through all groups, only 56 percent being grade 1 kernels (groups 1 to 3, inclusive). Type c is typical of a good smooth-shell tree, a large proportion of the nuts being grade 1. What poor nuts there are tend to be in group 6. Type d represents an extreme example of this tendency. This phenomenon might be ascribed to inherited characteristics or to early nutritional disturbances which later disappear since the distribution in the other groups is normal. Type e is a typical distribution for the rough-shell type. Whereas the smooth-shell type normally has few nuts in grade 2 (group 4), the rough-shell usually has a considerable percentage. This tendency to underfilling appears to be a characteristic of the rough-shell type rather than the result of nutritional disturbances. Type f shows how extreme this tendency may become with the rough-shell type.

SEASONAL CHANGES IN DISTRIBUTION

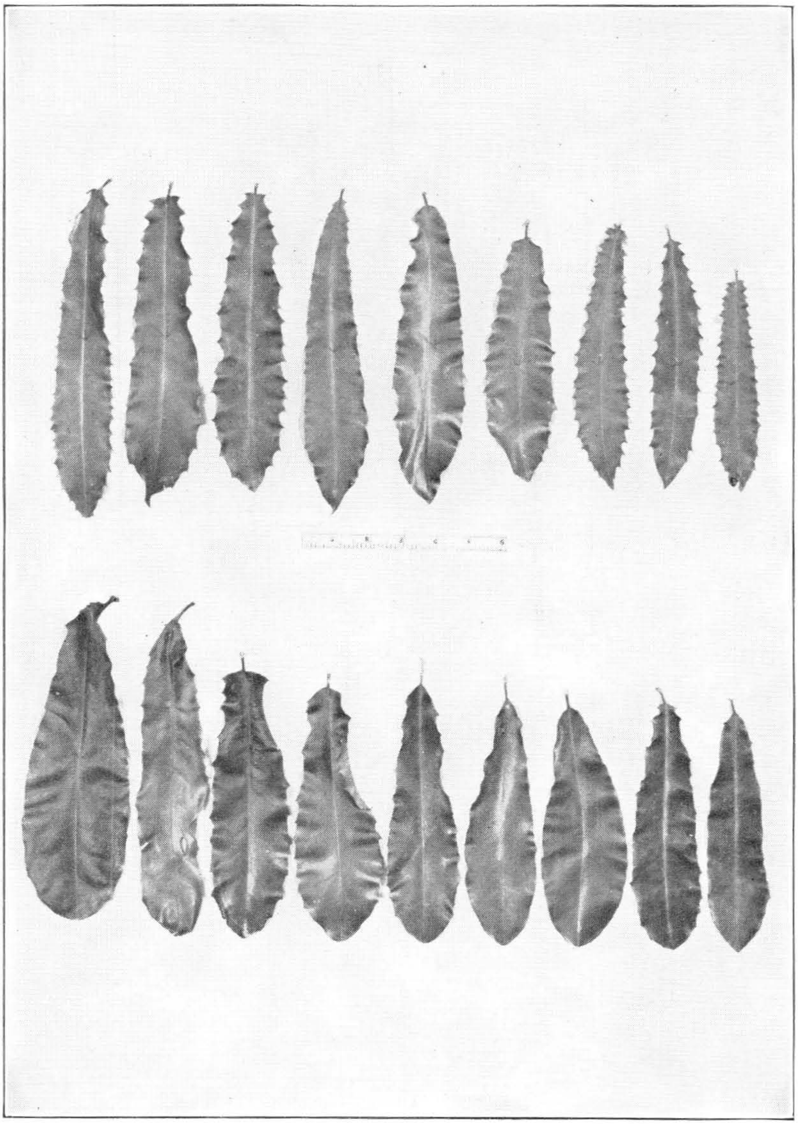
It has been previously noted that the crop varies in quality throughout the season, the first nuts which drop usually being poor in quality. If the tree is normal and in good condition, this represents only a small fraction of the crop. Sometimes this poor quality continues throughout the season. In table 9, tree No. 4 illustrates the rapid improvement in quality during the season, the bulk of the crop being borne during the last 3 months. With tree No. 10 the crop remained poor in quality throughout the season. This underfilling caused a marked decrease in the average weight per kernel and in proportion of kernel from that of the previous season.

TABLE 9.—*Seasonal changes in distribution in specific-gravity groups, smooth-shell type, Waipahu, Oahu*

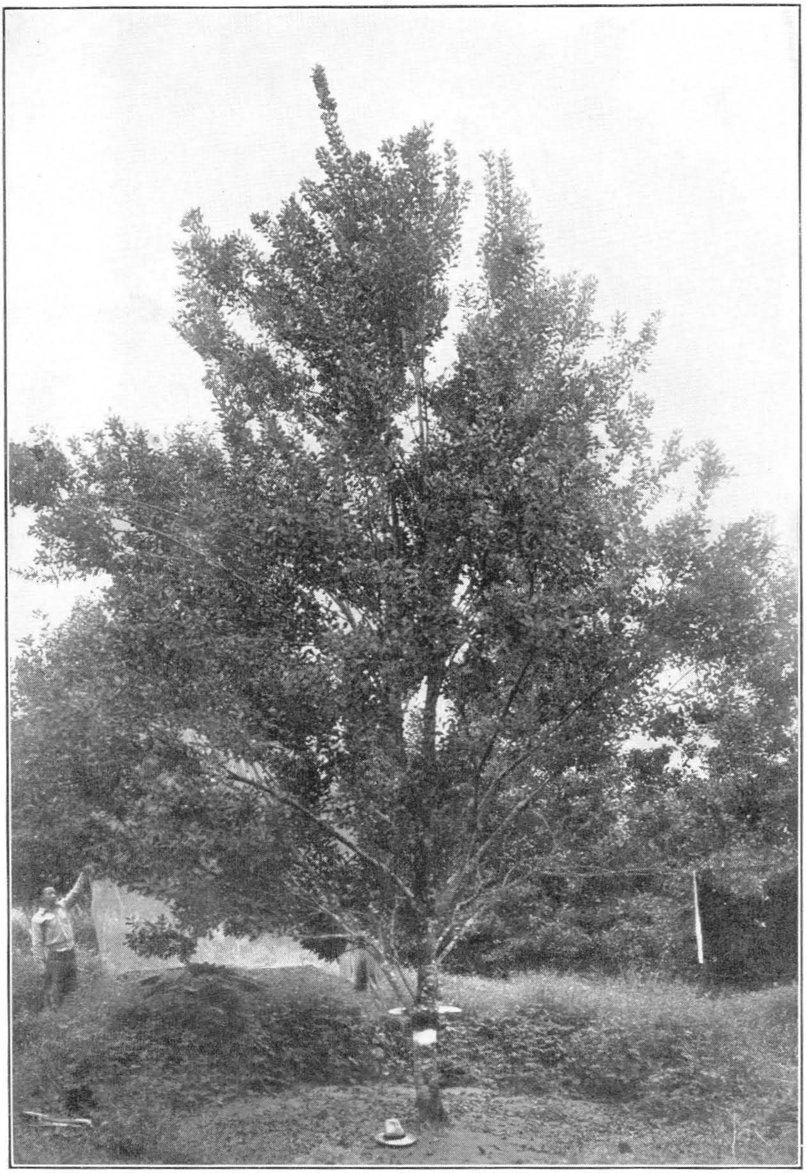
Tree and month of harvest	Proportion of kernel	Average weight per kernel	Percentage of kernels having a grade and specific gravity of—			
			Grade 1			Grades 2 and 3
			<0.970	0.970–0.985	0.985–1.000	>1.000
Tree No. 4:	*Percent*	*Grams*	*Percent*	*Percent*	*Percent*	*Percent*
1930 average	28.5	1.87	13	70	12	4
1931						
June	27.6	1.34	0	1	20	79
July	27.4	1.45	1	9	26	64
August	27.3	1.63	1	52	23	24
September	26.9	1.74	14	64	12	10
October	27.7	1.86	24	70	6	0
November	27.6	1.77	20	80	0	0
Tree No. 10:						
1930 average	40.7	1.91	41	58	0	1
1931						
July	36.8	1.45	6	52	14	28
August	35.7	1.28	2	28	26	44
September	35.9	1.37	7	25	23	45
October	36.5	1.37	13	25	18	44
November	37.5	1.44	20	21	18	41
December	37.1	1.39	19	27	16	38

YIELD AND NUT QUALITY OF SEEDLING TREES FROM DIFFERENT LOCATIONS

Study has been made over a period of years of representative trees from a number of the commercial orchards for the purpose of deter-



VARIATIONS IN SIZE AND SHAPE OF LEAVES FROM SMOOTH-SHELL SEEDLING TREES IN A SINGLE GROVE.



A 12-YEAR-OLD SEEDLING MACADAMIA TREE, SMOOTH-SHELL TYPE.
Seedling trees vary greatly in shape. This demonstrates an open tree with slender branches.

mining the extent of variation among seedling trees and the adaptability of the macadamia to various localities in Hawaii (pls. 5 and 6).

Certain changes were made in methods used during the progress of the project. Differences in facilities available at the different locations have likewise affected the type of data which could be collected. The data on the individual trees are, therefore, not the same for the different localities. On Oahu it has been possible to get monthly samples and individual tree yields. At the other locations the data are less complete. No individual tree yields could be had and the samples usually consisted of but one or two taken during the peak of the crop.

Tables 10 to 12 summarize the study of individual trees from Waipahu and Nutridge on Oahu, Kona and Kohala on Hawaii.

NUTRIDGE

Complete records were kept of the monthly yield and nut quality on eight trees at Nutridge over a 3-year period. The trees were planted at varying times, the average age being about 10 years. These trees were selected on the basis of some desirable quality such as yield or percentage kernel and hence do not represent a cross section of the orchard.

This grove is at an altitude of 600 to 800 feet and has moderate rainfall.

Table 10 shows that in all cases the season's average percentage of grade 1 kernels is very high, in all but three cases it is more than 90 percent. One tree, C-8-54, would be rated as commercially undesirable because of the large percentage of sizing culls in spite of good quality in other respects. The seasonal effect is apparent in C-14-156 where the size dropped badly in the 1935-36 harvest.

TABLE 10.—*Yield and nut characteristics of 8 smooth-shell-type seedling trees for 3 years, Nutridge, Oahu*

Tree No.	Year	Samples tested	Proportion of unshelled nuts >2.10 cm in diameter	Proportion of kernel	Proportion of kernels of grade 1	Quality ratio	Yield of unshelled nuts per year	Yield of grade 1 kernels per year
		Number	*Percent*	*Percent*	*Percent*		*Pounds*	*Pounds*
A-12-73	1933-34	6	95	30	88	4.05	51	12.6
	1934-35	9	100	29	93	3.70	65	17.6
	1935-36	7	100	29	92	3.81	69	18.1
A-13-83	1933-34	2	98	32	98	3.07	75	24.5
	1934-35	2	95	37	100	2.85	79	27.7
	1935-36	2	80	39	96	3.24	119	36.8
C-8-54	1933-34	6	74	40	92	3.72	48	12.9
	1934-35	3	48	34	97	6.32	22	3.5
	1935-36	1	23	36	98	12.42	---	---
C-8-57	1933-34	8	95	28	97	3.93	44	11.2
	1934-35	7	100	26	97	3.96	53	13.4
	1935-36	5	98	28	97	3.77	42	11.1
C-10-89	1933-34	8	97	29	87	4.07	33	8.1
	1934-35	5	99	31	99	3.28	38	11.6
	1935-36	1	83	33	93	3.87	---	---
C-14-154	1933-34	5	99	31	98	3.30	41	---
	1934-35	5	92	30	97	3.73	60	---
	1935-36	1	98	31	85	3.83	---	---
C-14-156	1933-34	5	85	39	96	3.17	44	13.9
	1934-35	7	88	35	99	3.29	37	11.2
	1935-36	6	43	36	92	7.02	47	6.7
C-28-415	1933-34	8	94	32	96	3.48	46	13.2
	1934-35	8	96	33	95	3.32	57	17.2
	1935-36	7	83	34	98	3.60	65	18.0

WAIPAHU, OAHU

Twelve trees were selected at random to determine the extent of variation in the Waipahu orchard. The orchard was about 8 years old. The location is at sea level and dry, the trees being irrigated when necessary. Each result is the average of five to seven samples taken throughout the bearing season. These trees are the same as in table 7. The results are given in table 11.

TABLE 11.—*Yield and nut characteristics of 12 smooth-shell-type seedling trees at Waipahu, Oahu, 1930–31 crop*

Tree No.[1]	Total yield of unshelled nuts	Proportion of kernel	Average weight per kernel	Percentage of kernels having a grade and specific gravity of— Grade 1: <0.970	Grade 1: 0.970–0.985	Grade 1: 0.985–1.000	Grade 1: Total grade	Grades 2 and 3: >1.000	Quality ratio	Yield of grade 1 kernels[2]
	Pounds	*Percent*	*Grams*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*		*Pounds*
1	65.1	32.4	2.02	9	61	21	91	9	3.42	19.1
2	48.1	33.3	1.72	14	63	14	91	9	3.33	14.5
3	57.4	31.5	2.02	8	84	7	98	2	3.24	17.7
4	55.9	28.5	1.87	13	71	14	96	4	3.65	15.3
5	43.1	22.9	1.85	8	58	29	94	6	4.64	9.3
6	43.8	28.5	1.87	2	62	27	90	10	3.91	11.2
7	53.5	24.3	2.00	9	67	17	93	7	4.38	12.2
8	66.6	28.8	2.24	13	79	5	97	3	3.58	18.6
9	36.2	20.9	2.41	6	58	24	88	12	5.43	6.7
10	54.6	40.7	1.91	41	58	0	99	1	2.48	22.0
11	52.1	31.8	2.23	20	67	8	96	4	3.28	15.9
12	47.6	30.1	1.86	21	64	12	96	4	3.46	13.8

[1] Same trees as in table 7.
[2] Total yield of unshelled nuts divided by quality ratio. No sizing of unshelled nuts was done during this time.

As noted in table 11 the proportion of kernels which are grade 1 is uniformly high. All trees but one bore 90 percent or more of grade 1 kernels. The variation in proportion of kernel is from 20.9 to 40.7 percent. The variation in yield of grade 1 kernels per tree of from 6.7 to 22 pounds is indicative of the possibilities for improvement of an orchard through elimination or top working of undesirable trees.

KOHALA, HAWAII

The trees in the Kohala orchard were 8 to 12 years old at the time of this test. The elevation is 400 feet above sea level and the rainfall about 40 inches. Only one sample was taken from each tree during the period of greatest nut drop. Results are given in table 12.

TABLE 12.—*Nut characteristics of 10 smooth-shell-type seedling trees at Kohala, Hawaii, 1933–34 harvest*

Tree No.	Proportion of unshelled nuts >2.10 cm in diameter	Proportion of kernel	Average weight per kernel	Percentage of kernels having a grade and specific gravity of—				Quality ratio
				Grade 1		Grade 2	Grade 3	
				<0.985	0.985–1.000	1.000–1.025	>1.025	
	Percent	*Percent*	*Grams*	*Percent*	*Percent*	*Percent*	*Percent*	
1	92	32.3	2.06	97		0	3	3.47
2	100	27.3	2.29	95		4	1	3.94
3	100	28.2	2.57	96		4	0	3.70
4	90	24.9	2.73	86		6	8	5.58
5	100	33.0	3.07	98		2	0	3.09
6	100	31.8	2.90	100		0	0	3.15
7	94	30.9	2.38	86		7	7	4.05
8	100	31.3	2.48	84		10	6	3.99
9	100	18.3	2.51	83		6	11	6.58
10	100	35.7	2.18	89		2	9	3.15

All trees are acceptable as to size of nut with a somewhat higher average weight per kernel than found in other orchards. The proportion of grade 1 kernels is also good. Trees 5 and 6 are exceptional in that they have unusually large kernels, 100-percent sizable nuts, and at the same time a relatively high percentage of kernels. This, together with very high proportion of grade 1 kernels, results in the low quality ratios of 3.09 and 3.15.

CORRELATION OF QUALITY OF KERNEL, WEIGHT OF UNSHELLED NUT AND KERNEL AND PERCENT OF KERNEL

A statistical examination was made of the data secured from nuts of individual trees of the smooth-shell type grown at Nutridge, Oahu (table 10), to determine the correlation between the different nut characteristics. The results given in table 13 are based on 139 individual samples of nuts.

TABLE 13.—*Correlation of quality of kernel, weight of unshelled nut and kernel, and percent kernel*

Variables		Coefficient of correlation (r)
Quality of kernel [1]	Weight of unshelled nut	−0.02
Do	Weight of kernel	+.02
Do	Percent of kernel	+.18
Weight of unshelled nut	Weight of kernel	+.68
Do	Percent of kernel	−.58
Percent of kernel	Weight of kernel	.01

[1] Percent of kernels which are grade 1 (i. e., with a specific gravity less than unity).

From table 13 it may be concluded that (1) quality cannot be improved by selection for weight of nut or of kernel or of percent kernel; and (2) weight of kernel can be increased by selection for weight of nut but in so doing the percent of kernel drops off.

DISCUSSION

Investigations by the Hawaii Experiment Station show the great variation in nut characteristics among the several thousand bearing macadamia seedlings throughout the Territory. Within a single orchard of the same type, the percent kernel may vary from 20 to 40 and the percent of grade 1 kernels (specific gravity less than 1) from 6 to 100. This percentage likewise may vary between wide limits for the same tree throughout the year as does the average value from one year to the next.

Samples from commercial shipments of nuts received at the factory from different orchards obviously show less fluctuation than those from individual trees. The variations are sufficiently great, however, to warrant their being taken into account in the purchase of the nuts. For example, the quality ratio of the crop from one location was 5.70 during July and August, 3.75 during September and October, and 4.22 for the remainder of the crop. Since quality ratio represents the pounds of nuts in the shell as received to produce 1 pound of grade 1 kernels, these differences are of vital importance, the nuts of 3.75 quality ratio having a value approximately double those of 5.70. Correspondingly greater differences result when nuts are purchased from different localities. It would seem sound commercial practice that some account be taken of these differences in quality ratio in fixing the purchase price for nuts harvested from seedling trees from different localities.

The fact that the composite crop from an orchard of bearing trees shows a small fluctuation in quality ratio compared with individual seedling trees is of course no argument for seedling trees. It simply means that the high-quality trees neutralize the low-quality, the upper limit being determined by the relative proportion of desirable and undesirable trees present.

The records on individual trees are of value chiefly in showing the nature and extent of variation in nut characters, comprising as they do representative trees from the principal orchards of the Territory. The study likewise has served to develop the tecnhique necessary in evaluating the nut characteristics. It has shown that records of nut quality should be made on a tree over more than one crop and during the entire bearing season if possible. If this is not possible, the samples should be taken during the peak of the nut drop over several seasons.

The differences between nuts from different localities were obviously the resultant of such factors as origin of seed, climate, culture, and the like. There are some indications that location affects kernel quality both as to percentage of grade 1 kernels, and the color of the kernel and the epidermis of the basal portion. From the standpoint of nut quality the best locations appear to be the relatively dry, leeward sides of the islands.

The results given herein would seem to show an inherent difference in nut qualities between the smooth-shell and rough-shell types of nuts. Horticulturally, the two types are distinct. They produce two different curves when specific gravities of kernels are plotted against the corresponding percentages of oil. The flavor, texture, and roasting qualities are likewise different. The rough-shell type appears more prone to underfilling of kernels and appears to show greater variability in this respect than the smooth-shell type. Public preference is generally for the smooth-shell type because of its mild flavor and crisp tender texture, although many prefer the more pronounced, sweeter flavor and firmer texture of the rough-shell type. The present commercial demand is almost entirely for the smooth-shell type and indications are that most of the rough-shell trees will be either eliminated or top worked.

The methods used in this study were devised primarily to evaluate the macadamia as a shelled processed kernel. As finally adopted, a sample is carried through the process of sizing the unshelled nut to eliminate small sizes, shelling, and specific-gravity grading to eliminate kernels of poor quality. The resultant quality ratio gives as a single value the pounds of nuts as received to produce 1 pound of grade 1 kernel. As such, the method has proved useful both in the experimental phases and as a commercial procedure.

SUMMARY

This bulletin reports investigations by the Hawaii Agricultural Experiment Station on development of methods for evaluating the macadamia nut from the standpoint of a shelled roasted product, and application of these methods to the evaluation of nuts from commercial orchards throughout the Territory.

It was found that the specific gravity of the macadamia kernel has a very high negative correlation with the percent oil (—0.985 for the rough-shell type and —0.979 for the smooth-shell type). The method thus serves as a rapid method for determining the oil content.

Specific gravity is likewise related to the roasting quality of macadamia kernels. It has been found that kernels may be graded as to roasting qualities as follows: Grade 1—specific gravity less than 1, grade 2—specific gravity between 1.000 and 1.025, and grade 3—specific gravity greater than 1.025. Only grade 1 kernels are used in present commercial packs.

A single value known as quality ratio was developed which designates the pounds of unshelled nuts as received to produce 1 pound of grade 1 kernels.

Individual seedling trees show great variation in nut characteristics, the large number of bearing trees furnishes ample material for selection as to size, percent kernel, and quality of kernel, as well as total yield.

There is evidence of significant difference in kernel characteristics between the rough-shell and smooth-shell types of macadamia nuts. The latter is the better type as judged by kernel quality and adaptation to the roasted pack.

Commercial shipments of unshelled nuts received at the factory show marked difference in quality ratio. It is believed that the purchase price of the nuts should be based on the quality ratio.

LITERATURE CITED

(1) CAMP, A. F.
[1930]. AVOCADO MATURITY STUDIES. Fla. Agr. Expt. Sta. Rept. 1929–30: 79–81.

(2) COLEMAN, D. A., and FELLOWS, H. C.
1927. OIL CONTENT OF FLAXSEED, WITH COMPARISONS OF TESTS FOR DETERMINING OIL CONTENT. U. S. Dept. Agr. Bull. 1471, 35 pp., illus.

(3) DRAKE, N. F.
1930. A METHOD FOR GRADING BLACK WALNUTS. Amer. Nut Jour. 32 (2): 28.

(4) FOTH, G.
1907. DIE BESTIMMUNG DES STÄRKE GEHÄLTES DER KARTOFFELN NACH DEM SPEZIFISCHEN GEWICHT. Ztschr. Spiritusindus. [Berlin] 30: 217–218. [Abstract by J. F. B. in Jour. Soc. Chem. Indus. 26: 705. 1907.]

(5) LEWIS, R. D.
1932. DETERMINATION OF OIL CONTENT OF PECANS. NEW SULFURIC ACID DIGESTION METHOD. Indus. and Engin. Chem., Analyt. Ed. 4: 296–297.

(6) NICHOLS, P. F., and REED, H. M.
1932. RELATION OF SPECIFIC GRAVITY TO THE QUALITY OF DRIED PRUNES. Hilgardia 6: 561–583, illus.

(7) POPE, W. T.
1929. THE MACADAMIA NUT IN HAWAII. Hawaii Agr. Expt. Sta. Bull. 59, 23 p., illus.

(8) SHUHART, D. V.
1932. ENDOSPERM AND EMBRYO DEVELOPMENT AS RELATED TO FILLING OF PECANS AND WALNUTS. Amer. Soc. Hort. Sci. Proc. (1931) 28: 161–163, illus.

APPENDIX

There is appended table 14 that shows seasonal variation in nut quality of commercial shipments of macadamia nuts from different bearing orchards in Hawaii.

TABLE 14.—*Scoring of factory shipments of smooth-shell-type nuts from different bearing orchards, 1935–36*

Entry No.	Date received	Weight of nuts received	Sizing (diameter) of unshelled nuts: Large, >2.75 cm	Sizing: Medium, 2.75–2.45 cm	Sizing: Small, 2.45–2.10 cm	Sizing: Culls, <2.10 cm	Proportion of kernel	Average weight per kernel	Percentage of kernels having a grade and specific gravity of—: Grade 1, <1.000	Grade 2, 1.000–1.025	Grade 3, >1.025	Quality ratio [1]
WAIPAHU, OAHU												
	1935	*Lb.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Grams*	*Pct.*	*Pct.*	*Pct.*	
209	July 26	146	4	38	50	8	24.7	1.70	50.8	26.9	22.3	8.64
225	Aug. 9	98	2	38	50	10	28.4	1.99	67.2	19.4	13.4	5.82
229	Aug. 16	108	6	42	47	5	28.6	2.01	68.3	19.6	12.1	5.30
231	Aug. 23	200	3	18	66	12	30.2	1.96	86.0	10.2	3.8	4.41
235	Sept. 6	184	4	28	54	13	31.4	2.11	86.5	9.2	4.3	4.29
Subtotal or average		736	3.9	32.9	53.5	9.7	28.7	1.95	71.8	17.0	11.2	5.69
295	Sept. 13	298	0	44	55	0	28.5	2.18	94.1	5.3	0.6	3.80
301	Sept. 20	283	2	24	69	6	32.4	2.07	95.2	2.2	2.5	3.49
389	Sept. 27	360	0	23	70	7	29.0	2.00	92.7	4.4	3.0	4.00
393	Oct. 4	463	5	26	65	4	28.5	2.04	96.3	1.7	2.0	3.87
445	Oct. 11		11	66	23	0	29.1	2.59	100.0	0	0	3.45
458	Oct. 30	541	4	41	48	7	28.0	2.16	95.7	3.5	.8	3.88
Subtotal or average		1,945	3.7	37.3	55	4	29.3	2.17	95.6	2.9	1.5	3.75
649	Dec. 9	546	6	36	55	3	27.0	2.17	93.5	4.0	2.5	4.09
817	do		9	34	52	5	25.3	2.07	96.0	3.8	.2	4.34
818	Dec. 13	273	8	28	57	7	27.3	1.94	98.3	1.3	.4	4.01
819	Dec. 20	568	10	32	49	8	24.1	1.82	98.1	1.1	.8	4.60
820	Dec. 27	462	9	38	43	10	26.5	2.09	99.5	0.5	0	4.21
	1936											
821	Jan. 3	382	11	36	47	7	26.5	2.03	95.3	2.1	2.6	4.26
822	Jan. 10	290	9	42	46	3	26.1	2.05	98.0	1.2	.8	4.03
823	Jan. 17	294	8	37	50	4	26.3	2.03	95.4	2.0	2.6	4.16
117	Jan. 24	189	4	29	61	6	27.1	2.00	92.2	5.8	2.0	4.27
Subtotal or average		3,004	8.2	34.7	51.2	5.9	26.2	2.02	96.3	2.4	1.3	4.22
Season total or average		5,685	5.8	35.0	52.9	6.2	27.7	2.10	90.00	6.2	3.8	4.27
NUTRIDGE, OAHU												
	1935	*Lb.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Grams*	*Pct.*	*Pct.*	*Pct.*	
205	July 2	231	5	35	56	4	28.8	1.95	73.7	22.4	4.0	4.90
207	July 12	321	5	26	60	9	28.5	1.96	74.5	15.7	9.8	5.18
222	July 27	336	90	10	0	0	25.7	2.87	62.8	22.1	15.2	6.17
224	Aug. 3	256	1	23	60	16	30.7	2.07	83.4	10.3	6.3	4.65
226	Aug. 10	425	8	22	57	13	28.1	2.00	83.0	7.0	9.7	4.94
230	Aug. 17	422	3	26	58	12	31.3	2.10	80.1	13.9	6.0	4.58
232	Aug. 20	143	0	0	100	0	33.0	1.87	89.9	3.2	6.9	3.37
233	Aug. 27	426	5	31	56	8	29.8	2.00	80.3	7.8	11.9	4.51
234	Sept. 3	776	8	42	43	7	31.6	2.19	82.1	12.4	5.5	4.10
Subtotal or average		3,336	13.8	23.9	54.5	7.8	29.7	2.11	78.9	12.7	8.4	4.71
294	Sept. 10	866	5	33	56	6	30.1	2.16	94.0	3.4	2.6	3.78
296	Sept. 14	124	0	0	100	0	31.8	1.89	90.5	7.0	2.5	3.45
297	Sept. 17	775	5	43	48	4	30.6	2.23	84.7	10.4	4.9	3.97
387	Sept. 24	739	6	38	50	5	29.3	2.23	87.6	9.1	3.4	4.15
390	Sept. 30	691	4	30	60	6	32.1	2.25	96.3	3.4	.3	3.46
447	Oct. 7	1,210	6	42	46	6	30.3	2.36	92.5	4.5	2.9	3.83
450	Oct. 14	1,210	6	37	49	8	31.0	2.27	94.4	4.7	1.0	3.70
453	Oct. 21	1,258	5	45	45	5	29.6	2.25	94.3	2.4	3.3	3.73
456	Oct. 28	1,154	5	50	41	4	30.4	2.24	96.0	2.2	1.8	3.61
644	Nov. 26	1,147	25	28	43	4	27.3	2.21	99.1	.8	0	3.90
646	Dec. 2	997	12	47	27	13	26.6	2.06	97.8	1.4	.8	4.36
648	Dec. 9	589	9	39	46	6	29.8	2.22	95.6	4.1	.3	3.71
812	do		13	40	37	10	29.4	2.29	97.3	2.2	.5	3.89

[1] Pounds of unshelled nuts required to produce 1 pound of grade 1 kernels.

TABLE 14.—*Scoring of factory shipments of smooth-shell-type nuts from different bearing orchards, 1935–36*—Continued

NUTRIDGE, OAHU—Continued

Entry No.	Date received	Weight of nuts received	Sizing (diameter) of unshelled nuts: Large, >2.75 cm	Medium, 2.75–2.45 cm	Small, 2.45–2.10 cm	Culls, <2.10 cm	Proportion of kernel	Average weight per kernel	Percentage of kernels having a grade and specific gravity of—: Grade 1, <1.000	Grade 2, 1.000–1.025	Grade 3, >1.025	Quality ratio
	1935	*Lb.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Grams*	*Pct.*	*Pct.*	*Pct.*	
813	Dec. 16	1, 242	11	41	43	5	29. 9	2. 37	98. 8	0	1. 2	3.[illegible]7
70	Dec. 23	485	0	2	87	11	34. 9	1. 81	95. 3	4. 7	0	3.[illegible]8
814	Dec. 30	690	9	33	51	7	28. 5	2. 48	100. 0	0	0	3.[illegible]7
	1936											
815	Jan. 6	814	6	0	91	3	29. 9	1. 83	97. 4	2. 1	. 5	3.[illegible]4
816	Jan. 13	427	14	38	42	6	28. 7	2. 26	97. 6	1. 3	1. 1	3.[illegible]0
81	Jan. 20	428	14	37	42	7	31. 0	2. 48	97. 6	1. 2	1. 2	3.[illegible]6
118	do		10	41	44	5	31. 1	2. 39	97. 7	2. 3	0	3.[illegible]6
119	Jan. 27	341	8	37	48	7	31. 2	2. 19	98. 2	. 6	1. 2	3.[illegible]2
Subtotal or average		15, 275	8. 4	33. 4	52. 1	6. 1	30. 2	2. 21	95. 4	3. 2	1. 4	3.[illegible]2
Season total or average		18, 611	9. 8	32. 0	51. 8	6. 2	30. 0	2. 19	90. 4	6. 0	3. 6	3.[illegible]2
KEAUHOU, HAWAII												
	1935	*Lbs.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Grams*	*Pct.*	*Pct.*	*Pct.*	
203	May 15		8	52	36	4	24. 2	1. 95	69. 2	21. 8	9. 0	6.[illegible]3
204	June 28	278	8	42	48	2	25. 4	1. 95	74. 3	12. 4	13. 3	5.[illegible]1
223	Aug. 2	529	94	6	0	0	24. 4	2. 91	73. 3	17. 2	9. 5	5.[illegible]8
228	Aug. 13	380	4	59	34	3	26. 1	2. 02	63. 7	16. 7	7. 5	6.[illegible]2
236	Sept. 3	647	6	58	33	3	27. 8	2. 20	85. 5	10. 0	4. 4	4.[illegible]1
251	Aug. 23	408	18	48	31	3	23. 7	2. 09	80. 4	13. 9	5. 7	5.[illegible]4
293	Sept. 9	380	15	49	34	1	25. 0	2. 04	84. 6	7. 5	7. 9	4.[illegible]8
299	Sept. 20	795	15	47	39	0	26. 0	2. 12	86. 4	6. 4	7. 2	4.[illegible]5
388	Sept. 24	739	11	37	45	6	25. 3	1. 98	82. 3	12. 8	5. 0	5. 1[illegible]
446	Oct. 3	485	25	52	23	1	26. 1	2. 26	78. 0	17. 1	5. 0	4. 97
449	Oct. 11	517	8	38	49	5	24. 7	1. 85	80. 1	13. 5	6. 4	5. 25
452	Oct. 18	611	12	48	38	2	25. 0	2. 04	79. 2	13. 2	7. 6	5. 15
455	Oct. 25	567	13	43	41	3	25. 6	1. 65	79. 2	14. 3	6. 6	5. 01
642	Nov. 15	695	23	37	26	13	34. 2	1. 93	52. 4	27. 6	20. 0	6. 45
645	Nov. 29	475	20	58	22	0	27. 0	2. 25	86. 2	11. 1	2. 7	4. 30
824	Dec. 12	417	24	50	26	0	25. 1	2. 16	88. 8	6. 8	4. 5	4. 48
	1936											
825	Jan. 10	716	25	48	27	0	24. 3	2. 12	84. 6	10. 9	4. 5	4. 86
116	Jan. 30	336	20	41	36	3	25. 9	2. 16	89. 3	6. 4	4. 3	4. 46
Season total or average		8, 975	19. 4	45. 2	32. 7	2. 7	25. 8	2. 09	78. 9	13. 5	7. 6	5. 11
HAIKU, MAUI												
	1935	*Lbs.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Grams*	*Pct.*	*Pct.*	*Pct.*	
227	Aug. 13	55	6	36	55	3	30. 2	1. 97	86. 5	4. 2	9. 4	3. 97
392	Oct. 2	221	12	36	47	5	27. 5	2. 02	90. 3	7. 1	2. 6	4. 32
457	Oct. 29	343	6	39	50	5	29. 1	2. 12	94. 7	3. 0	2. 3	3. 83
641	Nov. 15	212	7	50	40	3	27. 7	2. 14	94. 6	2. 1	3. 3	3. 90
643	Nov. 23	139	11	48	38	3	28. 3	2. 00	97. 4	1. 0	1. 5	3. 78
647	Dec. 5	269	23	46	30	1	27. 0	2. 09	99. 5	. 5	0	3. 76
826			13	44	37	5	26. 9	2. 44	97. 0	. 7	2. 2	4. 03
827	Dec. 24	373	8	54	33	5	29. 4	2. 05	99. 1	. 9	0	3. 61
Season total or average		1, 612	10. 8	44. 2	41. 2	3. 8	28. 6	2. 23	94. 9	2. 4	2. 7	3. 90
KALAHEO, KAUAI												
	1935	*Lbs.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Grams*	*Pct.*	*Pct.*	*Pct.*	
394	Oct. 7	932	5	28	57	10	28. 0	1. 91	90. 7	6. 3	2. 9	4. 38
828	Dec. 23	615	23	22	45	11	35. 3	2. 15	95. 8	2. 7	1. 5	3. 33
	1936											
120	Jan. 27	147	17	36	42	5	25. 1	1. 97	93. 2	5. 5	1. 3	4. 51
Season total or average		1, 694	15. 0	28. 7	48. 3	8. 7	29. 5	2. 01	93. 3	4. 8	1. 9	4. 07

U. S. GOVERNMENT PRINTING OFFICE: 1938