The Utilization of the Seeds of the Wild Perennial Gourds[1]

DON S. BOLLEY,[2] RALPH H. McCORMACK,[3] and LAURENCE C. CURTIS[4]

VEGETABLE oils and proteins are highly essential to our nation's economy. This was emphasized during and just after the war when the strategically short supplies of edible and industrial vegetable oils and proteins caused shortages as well as stimulated a search for new domestic sources. Currently, acre restrictions on cotton for the control of lint production will curtail further our normal production of vegetable oils and protein feed concentrates. Thus, any new and practical source, particularly a plant that can be grown in the United States on land that is not being used, would be of interest.

One of the authors, Curtis (4), proposed that the wild perennial gourds of the western and southwestern parts of the United States be investigated as possible new domestic oil and protein crops and that their oils and proteins be subjected to chemical, industrial, and biological evaluations to determine whether or not these plants should be tested under field conditions.

Because these studies, which are an outgrowth of that proposal, show that both the oil and protein of all three species, *Cucurbita foetidissima, Cucurbita palmata,* and *Cucurbita digitata,* do have possibilities in various industrial uses, it seems desirable to describe briefly the plants, their geographic distribution, and their possibilities of being grown economically.

Botanically, all three of these species have many common characteristics: they are perennial; and under favorable moisture conditions they propagate themselves asexually by producing large fleshy roots, the nodes; their normal habitat is in the arid and semi-arid areas; fruit is produced on trailing vines which are sent up from the crown of the root, and judging from the size of the root, the life expectancy of the plant must be many years. Roots 12 inches in diameter are not uncommon, and their length is variable. Some tap roots have been excavated beyond 15 feet, and one has been observed at a depth of 45 feet below the ground surfaces. A single plant of *Cucurbita foetidissima* in Arizona was reported having produced a crop of fruit each year for over 40 years. The mature fruit are eaten by cattle and horses, and the seeds are eaten by rodents. The dry seeds were used also by the American Indians as a food item.

The geographical distribution of *Cucurbita foetidissima* is much more widespread than *Cucurbita palmata* or *Cucurbita digitata*. *Cucurbita foetidissima* has been reported growing wild in the following 12 states and Mexico: South Dakota, Nebraska, Kansas, Missouri, Oklahoma, Texas, New Mexico, Colorado, Utah, Arizona, Nevada, and California. *Cucurbita palmata* has been found by Curtis only in California. It grows beside the highway and in the dry washes of the Imperial Valley and in certain sections of the Mojave Desert. Large stands have been found near Palm Springs, California. *Cucurbita digitata* is reported to be native to California, but Curtis has never found it in that state. In certain sections of the desert around Phoenix, Arizona, *Cucurbita digitata* has been found in large stands. Individual plants were observed in the areas between Deming and Lordsburg, New Mexico. It is reported to be indigenous to the upper Rio Grande Valley of New Mexico and Texas.

Because experimental plantings as yet have not come into bearing, only calculated yields of seed per acre can be made from single plants, or groups of plants, found growing in the wild. The production of fruit, as well as the size of the plants, varies with age, location, and genetic constitution. Many plants are barren while others nearby may have produced over a hundred fruits. One plant of *Cucurbita foetidissima* was found with a yield of 157 fruit. A single plant of *Cucurbita palmata* was observed with 134 fruit, and another plant of this species bore 78 fruit, which produced 5¼ pounds of dry seed. The wide range of variability existing in the wild populations indicates that superior high yielding individual plants can be selected, whch can be maintained and increased by clonal propagation. Conservative calculations indicate that yields of from 500 to 1,500 pounds of seed per acre could be expected.

For complete mechanization of the crop, certain pick-up attachments would have to be perfected for the already developed squash seed threshers. It is unlikely that gourds will be grown as a cash crop except on land which at present is in the low income class, or on western land which is too dry to produce wheat, cotton, or grain sorghum. Large scale experimental plantings of these gourds are contemplated to answer the questions as to whether they can be grown profitably.

The seeds used in this study were of the 1946 season. *Cucurbita foetidissima* was collected by J. Roy Quinby, superintendent of the Texas Agricultural Experiment Substation No. 12, at Chillicothe, Texas. Only *Cucurbita foetidissima* is found in that region, where it grows luxuriantly along the roadside and in fence rows. The seed of *Cucurbita digitata* were collected by Curtis at Litchfield Park, Arizona, and the seed of *Cucurbita palmata* were collected in the waste lands and dry washes of the Imperial Valley and the Mojave Desert of California.

Production of Oils and Meals

The gourd seeds were ground in a large coffee mill prior to solvent extraction of the oil. Two passes of the seed through this mill prepared a crushed seed, from which most of the oil could be extracted with hexane.

The extraction of 131.0 pounds of *C. digitata* seed produced 31.9 pounds of oil and 99.1 pounds of de-oiled meal, amounting to 25.0% of the seed as oil and 75.0% as meal. The extractions were carried out as four stage batch countercurrent extractions using a hexane to crushed seed ratio of 2:1 and a five-gallon pressure filter as extractor. The oil was separated

[1] Presented at spring meeting, American Oil Chemists' Society, May 1-3, 1950, in Atlanta, Georgia.

[2] National Lead Company.
[3] Pratt Institute.
[4] National Cottonseed Products Association.

from the hexane by vacuum distillation of the miscella in a stainless steel still with the last traces of solvent removed by sparging the hot oil with carbon dioxide gas.

A similar extraction and oil recovery procedure yielded 22.2 pounds of oil, 28.0% of the seed, and 57.8 pounds of de-oiled meal, 72.0% of the seed, from 80.0 pounds of *C. foetidissima* seed.

The amount of *C. palmata* seed available for processing was small, 7.6 pounds, so that in this case a simple co-current batch extraction was employed using three solvent charges in the ratio of hexane to crushed seed of 2:1. The yield of oil was 1.9 pounds, 25% of the seed, with the balance as meal.

The de-oiled meals were air-separated into two fractions, protein flour and crushed seed coating. These protein flours were light buff in color and had protein contents, as calculated from nitrogen analysis, ranging from 53.8% to 60.8%. The protein content of the seed coating fractions was high, 23.7% to 26.3%, indicating an incomplete separation of flour and shell. A larger yield of protein flour could be expected using better seed milling equipment.

The results of this processing are given in Table I.

TABLE I

Processing

	Foetidissima	Digitata	Palmata
Yield of oil	28.0%	25.0%	25.0%
Yield of flour	23.0%	18.7%	15.0%
% Protein in flour	60.8	60.2	53.8
Yield of shell	49.0%	56.3%	60.0%
% Protein in shell	24.5	23.7	26.3

A satisfactory yield of oil is obtained from the seeds, being somewhat greater than from soybeans and less than flaxseed. The protein content of the meal is about average for various oil seeds. The shell fraction can be separated from the flour, giving a flour of very high protein content.

Preparation and Evaluation of Proteins

Chemically purified protein was prepared from the ground seed protein flours by the procedure employed by Bolley and McCormack for Chinese tallow seed protein (3). The soluble seed constituents including soluble non-protein nitrogen, were extracted from the flour prepared as previously described, by treating one part of flour with 15 parts of dilute hydrochloric acid at a pH of 4.7. The solids were separated from the extract by centrifuging. Protein was then extracted from the wet solids from the centrifuge by treatment with sodium hydroxide solution adjusted to a pH of 11.0 in the ratio of 30 parts of alkaline solution to one part of original flour. The alkaline protein dispersion was freed of residual solids by centrifuging. The protein was recovered from this dispersion by reducing the pH to 4.7 with sulfur dioxide so as to coagulate and precipitate it. Coagulated protein was settled and the supernatant liquid withdrawn. The settled material was spray dried using a temperature, spray drier outlet temperature, of 125°F. The extraction, separation, coagulation, and settling operations were carried out at room temperature. Soybean, peanut, and linseed proteins were prepared from their respective protein flours by this same procedure in order to compare these materials with the gourd seed proteins. Nitrogen analyses and yields, calculated to a moisture-free basis, are given in Table II.

A standard Gardner Mobilometer was used to measure the viscosity yield value and thixotropic gain of 50 g. samples of the above proteins dispersed in 200 ml. of 0.2% sodium hydroxide solution. The method described by Doob, Williman, and Sharp (5) was used to estimate the color of the spray dried proteins. Results are shown in Table III.

TABLE II

Protein Preparation

	% N in Flour	% N in Protein	% Yield
C. foetidissima protein	9.8	16.0	38
C. digitata protein	9.7	15.3	42
C. palmata protein	8.6	15.3	37
Soybean protein	8.9	15.1	47
Peanut protein	8.2	15.9	45
Linseed protein	8.9	15.0	34

TABLE III

Physical Properties of Proteins

	Viscosity, Poises	Yield Value, g./sq. cm.	Thixotropic Gain, %	Color
C. foetidissima protein	0.16	0	20	4+
C. digitata protein	0.16	0	0	3+
C. palmata protein	0.19	0	26	3+
Soybean protein	1.00	4.6	230	2+
Peanut protein	0.18	0	180	5
Linseed protein	0.22	0	1,240	4+

The physical properties given indicate some differences between the gourd seed proteins and the other seed proteins. Since these proteins were all prepared by the same procedure, it is believed that these differences reflect a difference between the gourd seed proteins and the controls. The properties of the cucurbita proteins indicate however that they have industrial possibilities for such products as water paints, paper coating, adhesives, and textile sizes.

Evaluation of Oils

The gourd seed oils, prepared as previously described, were evaluated according to the procedure of Bolley and Gallagher (2). The same procedure has been used to characterize a number of other paint and varnish oils (3, 6). While the physical and chemical characteristics of these oils have been previously reported (1, 7), no study of their utilization in paints and varnishes has been published. The oils from the three varieties of gourds were compared to linseed and soybean oil. Since the gourd oils had a viscosity slightly greater than raw linseed or crude soybean oil, slightly heat bodied, refined linseed oil (C viscosity) and soybean oil (G viscosity) were used in the comparison.

Table IV gives the physical and chemical characteristics obtained.

The above data are in agreement with such values as have been previously reported in the literature. The reason for slight increase in expected viscosity is not known. Perhaps it results from some polymerization of the trienoic conjugated constituents, the viscosity being qualitatively proportional to the trienoic conjugation. The iodine value would classify the oils in drying characteristics close to a high iodine, unbodied soybean. However the appreciable percentage of triene conjugated components in *C. digitata* and *C. palmata* would certainly lead one to expect in-

TABLE IV
Physical and Chemical Characteristics

	Foetidissima	Digitata	Palmata	Linseed C	Soy G
Viscosity	B—	C	C+	C	F
Color	10—	6+	7+	7	5+
Appearance	Sl. Cloudy	Clear	Sl. Cloudy	Clear	Clear
Odor	Bland	Bland	Normal	Normal	Normal
Acid value	2.4	4.8	1.6	4.1	2.2
Saponification value	190.1	189.5	192.7	194.4	189.6
Acetyl value	1.0	7.3	6.6	6.1	5.0
Iodine value	133.6	137.0	139.2	166.1	119.0
% Unsaponifiable	1.72	2.59	1.61	1.87	1.15
% Ash	0.0103	0.000	0.0022	0.000	0.000
Refractive index	1.4737	1.4853	1.4862	1.4804	1.4765
Specific gravity	0.9213	0.9310	0.9289	0.9388	0.9358
% Dienoic conjugation	0	0	0	....	....
% Trienoic conjugation	1.27	14.24	18.35	....	....

creased rate of drying and heat bodying properties. As will be shown later, the performance of these oils is clearly influenced by the conjugated triene components. The performance of the oils is shown in Tables V, VI, VII, and VIII.

The bodying test (Table V) shows the effect of the conjugated triene components. *C. palmata* and *C. digitata* have a faster initial rate of viscosity increase than linseed while in the later stages when the more active constituents are used up, the rate is slower. This is the type of viscosity increase experienced when a small amount of tung is blended with linseed oil. The *C. foetidissima* bodies similarly to soybean oil. The color retention on all the oils is satisfactory.

The set-to-touch time (Table VI) with drier added was very rapid for the *C. digitata* and *C. palmata* oils. *C. foetidissima* was intermediate between linseed and soybean oils. All had satisfactory film hardness and small amounts of residual tack. The dried film solubility (Table VII) after six weeks indicated the formation of a good protective coating film structure for the gourd oils, being in general between linseed and soybean oils. The gourd oils also showed up well in cold water, hot water, and alkali-resistant tests (Table VIII). The significance of the reactivity test is that no difficulty would be indicated in the use of

TABLE V
Bodying Test

	Foetidissima	Digitata	Palmata	Linseed C	Soy G
Time to Q	184 Min.	54 Min.	46 Min.	78 Min.	95 Min.
Color at Q	9+	7+	8	8	8
Time to Z2	347 Min.	273 Min.	174 Min.	214 Min.	312 Min.
Color at Z2	12—	10	10	10	11+
Time to Z5	399 Min.	350 Min.	232 Min.	268 Min.	384 Min.
Color at Z5	12+	11—	11+	11	12
Time to Z8	462 Min.	428 Min.	302 Min.	318 Min.	455 Min.
Color at Z8	13+	12	12+	11+	13
Time to gel	525 Min.	485 Min.	362 Min.	340 Min.	480+ Min.

TABLE VI
Drying Test

	Foetidissima	Digitata	Palmata	Linseed C	Soy G
Set-to-touch	4⅔ Hr.	1¾ Hr.	1⅔ Hr.	2⅓ Hr.	8 Hr.
Dryness					
24 Hr.	8+	9	9	8+	8+
48 Hr.	8	9	8+	8+	8+
96 Hr.	8	9—	8	8+	8+
192 Hr.	8	8+	8	8+	9
Sward Hardness					
24 Hr.	6	7	6	3	4
48 Hr.	5	6	5	2	3
96 Hr.	4	4	3	2	5
192 Hr.	5	4	3	2	5

TABLE VII
Film Solubility

	Foetidissima	Digitata	Palmata	Linseed C	Soy G
% Soluble in water	13.9	12.6	14.3	13.2	15.9
Acid value of soluble	206.0	243.4	204.0	146.0	118.4
% Soluble in hexane	20.3	21.4	20.4	20.8	31.1
Acid value of soluble	147.0	145.6	129.5	95.7	81.7
% Soluble in acetone	81.5	79.7	62.4	48.5	97.7
Acid value of soluble	143.0	130.3	132.3	119.3	84.1
% Soluble in alcohol-benzene	88.7	85.6	71.1	53.2	98.2
Acid value of soluble	121.0	124.3	122.2	151.0	89.7

these oils with reactive pigments such as white lead, red lead, zinc oxide, etc.

Standard varnishes were prepared with the oils from *C. foetidissima, C. digitata* and compared with similar varnishes prepared from linseed and Soy G as described in the previously cited paper (2). There was insufficient *C. palmata* oil for the standard varnish tests. The results are given in Tables IX and X.

C. digitata oil behaves quite similar to linseed in the spar type varnish (Table IX). *C. foetidissima* processes a little more slowly but also makes a satisfactory varnish with the phenolic resin. In the less expensive type, lime rosin varnish (Table X), the gourd oils also can be used satisfactorily. Again the *C. digitata* behaves like linseed. However the *C. foetidissima* dries much more slowly than the soybean,

TABLE IX
Bakelite BR-254 Varnish

	Foetidissima	Digitata	Linseed C	Soy G
Cooking time	395 Min.	185 Min.	167 Min.	285 Min.
Set-to-touch	86 Min.	47 Min.	47 Min.	30 Min.
Dust free	146 Min.	117 Min.	105 Min.	50 Min.
Dryness				
8 Hr.	8+	8+	8	7+
24 Hr.	9+	9+	8+	9
48 Hr.	10—	10—	9	9
96 Hr.	10—	10	9+	10—
192 Hr.	10—	10	10—	10
Sward Hardness				
24 Hr.	3	3	4	2
48 Hr.	5	5	6	4
96 Hr.	6	6	12	5
192 Hr.	7	8	14	10
Cold water				
(Time to whiten)	Unaffected	Unaffected	Unaffected	Unaffected
(Time to fail)	Pass 192 Hr.	Pass	Pass	Pass
Hot water				
(Time to whiten)	Unaffected	Unaffected	Unaffected	Unaffected
(Failure)	Pass	Pass	Pass	Pass
Alkali				
(Time to whiten)	48 Hr.	48 Hr.	4 Hr.	40 Min.
Alkali				
(Time to fail)	650+ Hr.	650+ Hr.	650+ Hr.	42 Hr.

TABLE X
Limed Rosin Varnish

	Foetidissima	Digitata	Linseed C	Soy G
Cooking time	230 Min.	230 Min.	70 Min.	195 Min.
Set-to-touch	335 Min.	290 Min.	202 Min.	56 Min.
Dust free	455 Min.	360 Min.	322 Min.	216 Min.
Dryness				
8 Hr.	8—	8+	9	7
24 Hr.	9	9+	9	9—
48 Hr.	9+	10—	9+	8+
96 Hr.	10—	10—	10—	9
192 Hr.	10—	10—	10—	9+
Sward Hardness				
24 Hr.	3	6	9	1
48 Hr.	5	9	9	3
96 Hr.	6	9	22	3
192 Hr.	5	7	23	5
Cold water				
(Time to whiten)	2 Hr.	2 Hr.	3½ Hr.	17 Hr.
(Time to fail)	168 Hr.	168 Hr.	24 Hr.	43 Hr.
Hot water				
(Time to whiten)	Immediate	Immediate	2 Min.	Immediate
(Failure)	Broken blisters	White, dull	Pass	White, dull
Alkali				
(Time to whiten)	1 Min.	1 Min.	1 Min.	Immediate
Alkali				
(Time to fail)	2 Min.	2 Min.	25 Min.	7 Min.

TABLE VIII

Cold Water, Hot Water, and Alkali Resistance and Reactivity

	Foetidissima	Digitata	Palmata	Linseed C	Soy G
Cold water resistance					
Time to whiten	2 Hr.	96 Hr.	4 Hr.	3 Hr.	Remained clear 16 Hr.
Time to fail	24 Hr.	96 Hr.	24 Hr.	24 Hr.	
Hot water resistance					
Time to whiten	Immediate	3 Min.	Immediate	1 Min.	5 Min.
Failure	Broken blisters	Film removed	Broken blisters	Film removed	Soft, dull, white
Alkali resistance					
Time to whiten	Immediate	1 Min.	Immediate	Immediate	30 Min.
Time to fail	5 Min.	8 Min.	6 Min.	1 Min.	56 Min.
Reactivity (zinc oxide)					
Original viscosity, Ford cup	67 Sec.	103 Sec.	63 Sec.	98 Sec.	145 Sec.
% Increase					
24 Hr.	3.0	—8.7	—11.1	—47.4	—9.0
1 Wk.	—9.9	—17.5	—8.9	—34.7	—33.8

which seemed to dry abnormally fast in this series of tests. This might have been due to the use of a slightly bodied soybean oil.

C. foetidissima oil and *C. digitata* oil were compared to a C bodied linseed and a G bodied soy in standard paints. One of these paints contained a single pigment, zinc sulfide, (S.P.), the other was a standard formula containing white lead, titanium dioxide, zinc oxide, and asbestine (M.P.). Tests made on these paints gave the result shown in Table XI.

The paint tests (Table XI) indicated that *C. digitata* has definite possibilities as a general protective coating vehicle. As in the other tests, these oil properties are fairly close to linseed oil. *C. foetidissima* should also find a use in paints, but more caution should be exercised in view of its slower drying and tendency to form softer films.

TABLE XI

Paint Tests

	Foetidissima	Digitata	Linseed	Soy G
Appearance				
S.P.	Excellent	Excellent		
M.P.	Poor	Good		
Brushing				
S.P.	Fair	Poor		
M.P.	Fair	Excellent		
Consistency				
1 day S.P.	700 g.	375 g.	320 g.	149 g.
7 days S.P.	617 g.	340 g.	307 g.	149 g.
1 day M.P.	220 g.	161 g.	155 g.	186 g.
7 days M.P.	217 g.	162 g.	155 g.	184 g.
Dry to touch				
At 25°C. S.P.	8+ Hr.	3½ Hr.	8+ Hr.	8+ Hr.
At 25°C. M.P.	8+ Hr.	3¾ Hr.	6 Hr.	8+ Hr.
Water permeability				
S.P.	1.40	1.26	1.27	0.91
M.P.	0.70	0.69	0.63	0.52
Elongation				
S.P.	62.0	15.5	27.0	84.0
M.P.	12.0	2.0	3.0	8.0
Tensile strength				
S.P.	4.7	20.1	28.6	0.0
M.P.	21.4	32.5	50.4	9.0
Taber abrasion				
M.P.	700	407	253	724
Shear hardness				
S.P.	63	56	111	143
M.P.	230	200	200	234
Sward hardness				
S.P.	0	2	2	2
M.P.	9	7	7	6
60° Gloss				
S.P.	73	25	55	87
M.P.	10	7	28	31

Conclusions

The experiments described above indicate that the seeds from three species of wild perennial gourds, *Cucurbita foetidissima, C. digitata,* and *C. palmata,* have a potential value. Drying oils, high protein flour, and chemically purified protein may easily be obtained from the seeds by standard procedures used for other oil seeds. While the *C. digitata* and *C. palmata oils* are different than other natural drying oils, their evaluation would place them in the class with linseed oil for general use in protective coatings. *C. foetidissima* lacks the conjugated triene component so is a somewhat "softer" drying oil, more smilar to soybean. The wild gourds should continue to receive serious consideration as an oil seed crop, particularly for arid and semi-arid land.

Acknowledgment

Acknowledgement must be made to the University of Connecticut Graduate Research Fund for having allocated funds for the collection of the seed used in this study. Thanks are given to J. Roy Quinby of the Texas Agricultural Experiment Substation No. 12 at Chillicothe, Texas, for time and labor in collecting the seeds of *Cucurbita foetidissima.* The authors also wish to acknowledge the assistance of those members of the National Lead Company Research Laboratories who made many of the determinations reported.

REFERENCES

1. Ault, W. C., Swain, M. L., and Curtis, L. C., J. Am. Oil Chem. Soc., *24*, 289-90 (1947).
2. Bolley, D. S., and Gallagher, E. C., J. Am. Oil Chem. Soc., *24*, 146-9 (1947).
3. Bolley, D. S., and McCormack, R. H., J. Am. Oil Chem. Soc., *27*, 84-7 (1950).
4. Curtis, L. C., The Chemurgic Digest, *5*, 221, 223-4 (1946).
5. Doob, H., Willmann, H., and Sharpe, P. F., Ind. Eng. Chem., *34*, 1460-8 (1942).
6. Houston, G. W., Gallagher, E. C., and Bolley, D. S., J. Am. Oil Chem. Soc., *26*, 244-9 (1949).
7. Wood, J. W., and Jones, H. A., J. Am. Chem. Soc., *65*, 1783 (1943).

[Received May 8, 1950]