Composition of Jojoba Seed during Development

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ABSTRACT

Data were taken on developing jojoba (*Simmondsia chinensis* [Link] Schneider) seed to determine what differences should be expected in quantity and quality of wax and meal when seed is harvested before complete maturation. Analyses were carried out for seed wt; moisture, protein, and wax contents; fatty acid and alcohol composition of the wax; and amino acid composition of the meal of seed samples collected from a natural population in Aguanga, Calif., at weekly intervals from June 20 to maturity on August 15. Wax content of the seed increased rapidly during the first 4 weeks from 13.5-40.5% and slower later, from 43.6-49.4%. Protein content of the meal increased at a slow steady rate during the entire period from 22.3-32.6%. Seed harvested 20 days prior to full maturity had essentially the same wax and protein contents as mature seed; it had lower seed wt and excessively high moisture though. The amino acid content of the meal increased considerably between the first and last sampling from 13.40-26.18% by wt. Certain amino acids increased at a faster rate than others. Whereas major changes occurred in the fatty acid composition of the wax, the alcohol composition remained unchanged throughout the sampling period.

INTRODUCTION

The agronomic potential jojoba (*Simmondsia chinensis* [Link] Schneider) recently has been surveyed in considerable detail (1). In spite of the existing demand for jojoba wax for use in cosmetics, lubricants, candles, and pharmaceuticals, natural jojoba populations have not been used extensively as commercial sources of seed, because they are difficult to harvest. When completely mature, most jojoba seed dehisces and drops to the ground; recovery of seed from the ground is made difficult by the plant's bushy, low-branching growth habit. For this reason and to avoid seed losses to desert animals, attempts have been made to harvest jojoba seed before it dehisces. Since jojoba seed in a given natural population reaches maturity during a 3-4 week period, seed obtained by a single harvest includes seeds at different stages of development. It is of interest, therefore, to follow the changes that occur during development to determine what differences should be expected in quantity and quality of wax and meal when seed is harvested before complete maturation. In this report, data are presented on the moisture, wax, protein, amino acid, and fatty acid contents and composition of jojoba seed harvested over a period of 2 months preceding maturity.

MATERIALS AND METHODS

Samples of seed were obtained from the large native stand of jojoba in the vicinity of Aguanga, Calif. Sampling started June 20, 1973, and continued at weekly intervals until August 15, 1973. On each sampling day, the 50 most developed, i.e. largest, seeds were hand-collected from each of 15 plants. Moisture was determined by comparing the seed's initial wt, without the capsule walls, with its wt after drying in a vented oven at 80 C until sample wt at successive weighings remained constant. The seed was then pressed in a Carver Laboratory press to 703 kg/cm^2, and the wax collected from each sample was used for gas liquid chromatography (GLC) analysis. Mechanical pressure removed a portion of the wax, only which in mature seed amounted to ca. 35% of the total dry wt of the seed sample. The remainder of the wax was removed as follows: meal was placed in 15 ml vials filled with 30-60 C BP petroleum ether. The vials were stoppered and placed in a vented oven at 35 C. Petroleum ether was decanted and replaced 3 times at 24 hr intervals; after the third decantation, the meal was dried at 80 C for 48 hr and then reweighed. Wax content of dried seed samples was determined by wideline NMR. A comparison of the initial dry seed wt and the wt of the meal following termination of the solvent extraction gave an additional estimate of wax content. Protein content of the meal (N x 6.25%) was determined on duplicate meal samples from each seed sample by Kjeldahl analysis. Two bulk samples of meal were prepared for each of the eight harvest dates for amino acid analysis; each of the 2 bulk samples taken for each date was prepared by combining 500 mg meal from the seed of each of the 15 plants harvested on that date. Amino acid content of these samples was determined with a JLC-5AH amino acid analyzer. Three bulk wax samples were prepared for each of the 8 harvest dates for GLC analysis; each of the 3 bulk samples taken for each date was prepared by combining 500 μliter wax from the seed of each of the 15 plants harvested on that date. GLC analyses were made with a Beckman GC-4 gas chromatograph connected to a Datex DIR-1 digital electronic recorder, as described by Miwa (2).

TABLE I

Wax Content and Protein Content of Wax-Free Meal and Moisture Content and Seed Weight (g) of Jojoba Seed[a,b]

Harvest dates	Wax (%)	Protein (%)	Moisture (%)	Seed dry wt (g/seed)
June 20	13.5a	22.3a	71.8a	.06a
June 27	20.4b	24.3b	65.9ab	.08a
July 4	27.8c	25.7c	60.3bc	.14b
July 11	40.5d	29.0d	56.2c	.25c
July 18	43.6de	29.8d	45.6d	.25c
July 25	47.6ef	30.8e	41.3d	.26cd
August 3	49.8f	31.6e	24.6e	.29d
August 15	49.4f	32.6f	10.3f	.34e

[a]Seeds harvested in Aguanga, Calif., on different dates. Data represent means from 15 single plant seed samples.

[b]Data on % wax and % protein are given on a moisture free basis. Means followed by the same letter in each column are not different at the 5% level of significance.

TABLE II

Amino Acids (Bound and Free) in Wax-Free Meal of Jojoba Seed[a]

Amino acids	(A) June 20	(A) August 15	(B) June 20	(B) August 15
Aspartic acid	1.14	2.58	8.43	9.86
Threonine	.56	1.37	4.18	5.23
Serine	.61	1.23	4.55	4.70
Glutamic acid	2.37	3.09	17.70	11.80
Proline	1.38	1.40	10.30	5.35
Glycine	.74	2.47	5.52	9.43
Alanine	1.00	1.27	7.46	4.85
1/2 Cystine	.10	.41	.75	1.57
Valine	.76	1.72	5.67	6.57
Methionine	.22	.27	1.64	1.03
Isoleucine	.58	1.14	4.33	4.35
Leucine	1.05	2.06	7.84	7.87
Tyrosine	.40	1.27	2.98	4.85
Phenylalanine	.56	1.29	4.18	4.93
Lysine	.70	1.68	5.22	6.42
Histidine	.28	.65	2.09	2.48
Arginine	.96	2.28	7.16	8.71
Totals	13.40	26.18	100.	100.00

[a](A) = percent of each amino acid by wt in the meal, and (B) = percent of each amino acid in relation to the total of amino acids recovered. Data represents means of two bulk meal samples, each from 15 single plant seed samples/date of sampling. Changes in percent amino acids on successive dates of sampling followed a linear pattern. Data for intermediate dates may be obtained by writing to the author.

RESULTS AND DISCUSSION

Major changes following definite trends were observed in the qualitative components of the seed samples studied during development.

Immature seeds harvested on June 20 had high moisture content (71.8%) but had low seed wt, protein, and wax contents (0.06 g, 22.3 and 13.5%, respectively). On that date, seed wt and protein and wax contents represented 17.6, 68.4, and 27.3%, respectively, of the maximum values reached for each one of these traits at maturity (Table I). With advancing development, the seed moisture content dropped rapidly and reached a level of 9-11% in mature seed on August 15, i.e. in seed which would become detached from the maternal plant and would drop to the ground if these plants were shaken mildly, mechanically, or by wind. Conversely, single seed wt increased very rapidly at first, between June 20 and July 11, from 0.06-0.25 g and somewhat more slowly from July 11 on until it reached 0.34 g at maturity. Changes in seed wax content paralleled the pattern of the increase in seed wt, but at a slower rate, i.e. 13.5-40.5% from June 20 to July 11, to 49.4% at maturity. The wax content data presented in this report are those obtained by NMR analysis. The data obtained by the extraction method were consistently lower by ca. 2.2%, but they had the same distribution as the NMR data. The coefficients of variation of the two methods did not exceed 4.2 and 5.3%, respectively, for any date of sampling. The increase in protein content occurred at a slow steady rate, from 22.3% on June 20 to 32.6% at maturity.

Thus, seed harvested as early as 20 days before full maturity would have practically the same wax and protein content as mature seed. The yield of wax and protein/plant, however, would be lower by ca. 25% due to the lower dry wt of immature seed. The component that would introduce serious difficulties if immature seed were harvested would be the seed moisture content. Since about half of the wt of seed harvested on July 25 represents water, effective measure would have to be taken to dry seed as it is harvested.

Changes in total amino acid content of the wax-free meal of jojoba seed are shown in Table II. Amino acids accounted for 13.4% of the wax-free meal on June 20 and for 26.2% at maturity. Thus, while the quantity of nitrogen in meal increased by ca. 50% between June 20 and August 15, the quantity of amino acids increased by 100%. The most likely explanation for the higher increase in amino acid content is that immature seed contained a higher proportion of nonprotein nitrogen than mature seed and that the ratio of nonprotein to protein nitrogen decreased as the seed approached maturity. The relative quantity of protein, as percent of meal of mature seed, was not much greater than that of meal of immature seed harvested on July 25; the quantity of amino acids in the former case, however, was 25% greater than that of the latter. Whereas the quantity of the majority of amino acids in percent of the meal by wt increased substantially between the first and last sampling dates, the percent content of meal in methionine, alanine, and proline remained rather stable. In terms of the percent of each amino acid of the total amount of amino acids recovered, major upward changes were observed with glycine and tyrosine and downward changes with glutamic acid, proline, alanine, and methionine.

The GLC analysis of fatty acids and alcohols leads to the following four noteworthy observations (Table III): (A) major changes occurred in the fatty acid components of the wax at progressive stages of seed development; (B) no change occurred in the alcohol components, which appeared to be unaffected by stage of seed development. The pattern of alcohols observed in wax of mature seed already was determined on June 20 when seed weighed as little as 17.6% of the maximum dry wt reached at maturity (Table I); (C) during the 8 weeks sampling period, palmitic and oleic acid decreased from 2.6 to 0.8% and from 16.1 to 7.0%, respectively. By contrast, eicosenoic and erucic acids increased from 26.3-36.4% and from 5.0-5.8%, respectively; (D) changes in fatty acid composition occurred very rapidly, so that the wax composition of seed collected on July 25 was essentially identical to that in seed collected on August 15. No major changes were detected in the minor acid and alcohol components of the wax (2), and no date are presented on them. Thus, jojoba seed harvested as early

TABLE III

Fatty Acids and Alcohols in Jojoba Wax from Mature and Immature Seed[a]

Number of carbon atoms and double bonds	Percent acids			Percent alcohols		
	Seed collected on:			Seed collected on:		
	6/20	7/25	8/25	6/20	7/25	8/15
16:0	2.6	0.9	0.8			
18:1	16.1	7.7	7.0			
20:1	26.3	35.3	36.4	28.4	27.7	28.8
22:0				5.2	5.4	5.4
22:1	5.0	6.0	5.8	16.5	16.9	15.8

[a]Data represent means from 3 bulk wax samples, each from 15 single plant seed samples/date of sampling. Data for intermediate dates may be obtained by writing to the author.

as 20 days before maturity produces wax of practically identical composition as mature seed. An earlier survey of seed wt (D.M. Yermanos, unpublished data) over larger areas gave a mean seed wt of .53 g/seed. It would be of interest to extend the present study to larger seeded strains to verify that comparable changes occur in developing seed of greater seed wt.

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