covered silo, the temperature reached a peak of 133°F at the end of ten days, leveled off at that point for 33 days, and then dropped following cold, rainy weather. After 33 days at 130–133°F, there probably was not much organic matter left to oxidize in the top ft of silage.

The temperature in the covered silo at the one-ft level peaked at 106°F within 24 hours after filling and gradually decreased to normal silage temperatures of around 75–80°F after ten days. The temperature remained at this level until the windy and rainy weather at day 33, at which time it rose to 95°F. This probably resulted from air getting into the silage pack during the windy weather because of inadequate sealing with the polyethylene.

The monitoring site at the two-ft level below the surface of the uncovered silo showed a gradual increase in temperature up to 110°F after 33 days of storage, indicating the oxidative effects of air entry into the pack at two ft below the surface level. Temperature at the two-ft level in the covered silo peaked at 89°F at day 5. It gradually decreased to 85°F at day 13 and stayed below 85°F for the duration of the trial.

As might be expected, neither the covered nor the uncovered monitoring sites showed any effects of air entry at three feet below the silage surface. Only an initial 5°F rise was exhibited at the 24-hour monitoring due to trapped air in the silage pack. By the third day, the temperature at the three-ft depth in both silos had dropped to 78°F and remained near there throughout the trial.

These trials showed that a 6 mil black polyethylene cover effectively excludes air from the silage pack when well weighted down. Lower temperatures in the covered silo showed that oxidation was greatly retarded and resulted in a reduced spoilage rate of the silage material in both the oat and corn silages. The temperature probes in the corn silage demonstrated that silage at least two feet down in the pack was being affected by air entry and oxidation in the uncovered silo.

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# *Wax and meal changes in* JOJOBA SEED

Wax content of jojoba seed increased rapidly from the first to the fourth week. Protein content of jojoba meal increased at a slow, steady rate during the entire period. Seed harvested 20 days prior to full maturity had essentially the same wax and protein content as mature seed, but it had lower dry seed weight and excessively high moisture content.

LABORATORY EVALUATIONS of jojoba wax indicate that it is a unique product with a wide spectrum of potential industrial applications. The major drawback which prevents extensive commercial utilization of jojoba wax at present is the limited supply of seed. Seed can only be obtained from native plant populations in California, Arizona, and Mexico. These sources are inadequate not only because they cannot produce sufficient quanities of seed to meet the anticipated demand, but also because: (1) total potential production from these populations can only be guessed at because they have never been harvested systematically and thoroughly; (2) fluctuations in climatic conditions cause major changes in seed yield, compounding the uncertainty about seed availability; and (3) experience gained to date in California indicates that native jojoba populations can only be harvested efficiently by hand. Thus these plants constitute a seed source which is highly unpredictable, expensive, and of unknown productivity. Despite these shortcomings, however, harvest must continue, at least until seed can be supplied by cultivated jojoba plantations. Any information that contributes to maximizing harvest efficiency is of great importance as long as seed production is dependent on native stands.

When jojoba seed is mature it gradually separates itself from the maternal plant and drops to the ground. Although seed collected from the ground has maximum wax content and dry seed weight and minimum moisture content, the plant's bushy, low-branching growth habit and the length of the dehiscence period, which extends over several weeks, makes seed collection from the ground difficult. In harvesting trials in California over the last three years, seed has been collected as close to maturity as possible before dehiscence. But this practice gathers seeds at different stages of development, so that it becomes important to investigate differences in quantity 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 content, and composition of jojoba seed harvested during eight weeks preceding maturity.

Seed samples were obtained from the large native stand of jojoba in the vicinity of Aguanga, California. Sampling started June 20, 1973, and continued at weekly intervals until August 15, 1973. On each sampling day the most developed (i.e., largest) seeds were hand-collected from each of 15 plants. Moisture was determined by comparing the seed's initial weight, not including the capsule walls, with its weight after drying in a vented oven at 80° C until sample weight at successive weighings remained constant. The seed was then pressed in a Carver laboratory press to 703 kg/cm², and the wax collected from each sample was used for gas-liquid chromatography analysis. Protein content of the meal ($N \times 6.25\%$) was determined on duplicate meal samples from each seed sample by Kjeldahl analysis. Amino acid content of these samples was determined with a JLC-5AH amino acid analyzer.

Major changes following definite trends were observed in the qualitative

# DEVELOPMENT

DEMETRIOS M. YERMANOS

components of the seed samples studied during development. As shown in the graph, immature seeds harvested on June 20 had high moisture content (71.8%), but had low seed weight, protein, and wax content (0.06 g, 22.3% and 13.5% respectively).

On that date, seed weight, protein, and wax content represented 17.6%, 68.4% and 27.3%, respectively, of the maximum values reached for each one of these traits at maturity. With advancing development, seed moisture content dropped rapidly and reached 9–11% in mature seed on August 15. Conversely, single seed weight increased very rapidly at first, between June 20 and July 11, from 0.06 g to 0.25 g, and then increased somewhat more slowly from July 11 until it reached 0.34 g at maturity. Changes in seed wax content paralleled the pattern of increase in seed weight, but at a slower rate, i.e., 13.5% to 40.5% from June 20 to July 11, to 49.4% at maturity. 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 per plant, however, would be lower by about 25%, because of the lower dry weight of immature seed. Since about half of the weight of seed harvested on July 25 represented water, effective measures would have to be taken to dry seed as it was harvested, to avoid molding.

Changes in total amino acid content of the wax-free meal of jojoba seed are shown in table 1. 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 about 50% between June 20 and August 15, the quantity of amino acids increased by 100%. The most likely explanation for the higher rate of increase in amino acid content is that immature seed contained a higher proportion of non-protein nitrogen than mature seed and that the ratio of non-protein 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 in the latter.

The following observations were made in relation to wax composition shown in table 2: (1) major changes occurred in the fatty acid component of the wax at progressive stages of seed development; (2) no change occurred in the alcohol component, which appeared to be unaffected by stage of seed development. The pattern of alcohols observed in wax of mature seed was already determined on June 20 when seed weighed as little as 17.6% of the maximum dry weight reached at maturity; (3) during the eight-week 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 acid increased from 26.3% to 36.4% and from 5.0% to 5.8%, respectively; (4) 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. Thus, jojoba seed harvested as early as 20 days before maturity produces wax of practically identical composition as mature seed.

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TABLE 1. AMINO ACIDS IN THE WAX-FREE MEAL OF JOJOBA SEED

| Amino Acids* | Percent by weight | | Percent of total amino acids recovered | |
|---|---|---|---|---|
| | June 20 | Aug. 15 | June 20 | Aug.15 |
| Aspartic acid | 1.13 | 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 |
| ½ 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 | 100.00 | 100.00 |

* Data represent means of two bulk meal samples, each taken from 15 plants. 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.

TABLE 2. FATTY ACIDS AND ALCOHOLS IN JOJOBA WAX FROM MATURE AND IMMATURE SEED

| Number of Carbon Atoms and Double Bonds | Percent Acids* | | | Percent Alcohols | | |
|---|---|---|---|---|---|---|
| | 6/20 | 7/25 | 8/15 | 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 |

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

CHANGES IN QUALITY COMPONENTS OF JOJOBA SEED AND MEAL: PERCENT MOISTURE AND WAX CONTENT OF THE SEED, SEED WEIGHT AND PERCENT PROTEIN CONTENT OF THE WAX FREE MEAL