number of samples from more varieties will be useful in verifying the observed variations.

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Sunflower Oil Quality and Quantity As Affected by Rhizopus Head Rot

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ABSTRACT

Sunflower seed (*Helianthus annus* L.) from plants infected with head rot caused by *Rhizopus* spp. exhibited serious oil quality problems. Free fatty acid content of this oil was 19.4%, compared with 0.8% for oil from seed of healthy plants. Oil from diseased seed was also higher in palmitic, stearic, arachidic, behenic and lignoceric fatty acids. In addition, diseased plants yielded only 81% as much seed and only 55% as much oil.

INTRODUCTION

Although historically considered a disease of little consequence (1,2), head rot of sunflower (*Helianthus annuus* L.) caused by *Rhizopus* spp. (probably *R. arrhizus* Fischer) reduced yield up to 60% in some fields in Texas in 1977. The increasing incidence of plants infected with Rhizopus is largely due to poor insecticidal control of the sunflower moth [*Homoeosoma electellum* (Hulst)] (3,4). Feeding by larvae of this moth predisposes the head to Rhizopus infection.

Little is known about the effects of this disease on oil quality in sunflower (2,5,6). Our objectives were to more adequately define oil quality of infected heads, and to determine the impact of this disease on oil and achene yields.

MATERIALS AND METHODS

One hundred 'Hybrid 896' sunflower heads infected with Rhizopus head rot and containing sunflower moth larvae were havested from our sunflower nursery at Bushland, Texas, in July of 1977. Heads from healthy plants in the same nursery served as controls. All heads harvested appeared to have physiologically mature seed. Head diameter was determined for each head, as well as percent of the head covered with Rhizopus infection and insect frass. These two latter measurements will subsequently be referred to as percent Rhizopus and percent frass. Seed samples were taken from three areas of the heads: (A) the Rhizopus-infected part of the head, (B) a portion of the head covered only with frass from feeding larvae of the sunflower moth, and (C) from a healthy portion of the head (no Rhizopus or frass evident). The samples were taken by pressing a round steel container (5 cm diameter) into the upper surface of the sunflower head. All seed within the marked circle composed the sample. Fresh

TABLE I

Measurements of Sunflower Seed from (A) Rhizopus-Infected Part of Head; (B) Area of Head Covered with Frass from Sunflower Moth Larvae; (C) Uninfected, Nonfrass Area; and Seed from Healthy Plants (Control)

	Area of Rhizopus-infected head			
	A	B	C	Healthy control
Fresh weight of 100 seed (g)	9.2 b[d]	11.1 c	11.8 d	6.6 a
Dry weight of 100 seed (g)	4.1 a	4.1 a	4.4 a	5.2 b
Achene oil content (%)[a]	27.7 a	31.3 b	32.8 b	44.8 c
Oleic fatty acid (%)[b]	49.8 b	50.4 b	51.6 b	43.7 a
Linoleic fatty acid (%)[b]	35.3 a	34.3 a	32.9 a	43.8 b
Free fatty acid (%)[c]	19.4 b	0.6 a	0.6 a	0.8 a
Unfilled achenes (%)	5.7 b	1.7 ab	1.6 ab	0.0 a

[a]Dry-weight basis.

[b]Expressed as a percent of oil and determined by refractive index method.

[c]Expressed as a percent of oil.

[d]Mean values on each line followed by a common letter are not significantly different according to Duncan's multiple range test (0.01).

TABLE II

Analysis of Seed Samples from Rhizopus-Infected and Uninfected Portion of Heads

	Palmitic		Stearic		Oleic		Linoleic		Arachidic		Behenic		Lignoceric		Total oil	
	D[a]	U[b]	D	U	D	U	D	U	D	U	D	U	D	U	D	U
Mean percent	11.32	6.02	8.35	6.03	51.18	57.53	25.63	28.54	1.73	0.58	1.04	0.85	0.71	0.28	27.68	32.80
Standard deviation	1.95	0.84	0.97	1.03	9.32	6.48	10.25	7.45	0.50	0.15	0.17	0.10	0.41	0.04	6.31	7.10
Significance[c]		**		**		NS		NS		**		*		**		**

[a] D = Diseased.
[b] U = Uninfected portion of head.
[c] *, ** Significant at the 0.05 and 0.01 levels, respectively.

weight of seed from each area was determined, and subsamples were dried at 130 C for 3 hr. Oil contents were determined on dried seed with a Newport NMR analyzer (7). The precision of the NMR analyzer with the 2 min 11 sec intergration time was ± 0.1%. Dry weight of 100 seed and percent unfilled seed were also determined on the oven-dry samples. Seed and oil yield reductions were determined by comparing the average of the three portions of the infected plant with the healthy plant yields.

Fatty acid composition of seed oil was estimated by two methods. Oil for the refractive index method (8-10) was obtained by pressing seed in a 2.54 cm stainless steel cylinder and piston assembly. Oil exuded from the bottom of the piston was picked up on a small glass rod and applied to the prisms of a Bausch and Lomb Abbe 3-L refractometer equipped with a circulating water temperature control mechanism, and refractive index was determined. Oleic acid and linoleic contents of the oil were calculated using the formulas developed by Goss (9). Samples from the three areas of each head and control seed from healthy plants were analyzed. The experimental design was a complete block, and significant means were identified with Duncan's multiple range test.

Fatty acid composition of solvent-extracted oil was determined by gas liquid chromtography (11). An electronic digital integrator was used to determine the amounts of individual fatty acids. In these analyses, only seed samples from the Rhizopus area and from the healthy area of each infected sunflower head were analyzed. A paired-t test was used to test for significance between samples.

We estimated oil quality deterioration by determining percent free fatty acid from oil samples from the three areas of each infected head and from seed of healthy plants. Oil obtained by pressing the seed was dissolved in hot isopropyl alcohol and titrated with 0.003 N alcoholic NaOH with phenophthalein as an indicator. Percent free fatty acid was calculated and differences among treatments were evaluated with Duncan's multiple range test.

Simple correlations (n = 100) were calculated for (1) percent Rhizopus with head diameter, (2) percent Rhizopus with percent frass, and (3) percent frass with head diameter.

RESULTS AND DISCUSSION

Oil Quality

The oil produced in infected heads had serious quality problems. Of major concern is the elevated level of free fatty acids (Table I). The degree of rancidity indicated by the level of free fatty acids would contribute a serious problem even if only a few plants were infected. Evidently this effect of disease on free fatty acids was not systemic because seed from uninfected parts of the head were normal in free fatty acid content.

Fatty acid composition of oil (which determines suitability for different uses) was also altered by this disease. The proportions of oleic and linoleic fatty acids were not significantly changed as determined by gas chromatography (Table II). However, the total percentages for these two acids were 76.8 for diseased and 86.1 for the uninfected portions of the head. The amount of oleic was increased and the amount of linoleic was decreased according to determinations made by the refractive index method (Table I). According to that analysis, each fatty acid in samples from all three parts of the head differed significantly from that of the healthy control. Although more samples were analyzed, this method of determination probably had more error than the gas chromatography method. Two possible sources of error in using this method were, first, that the

formulas used to calculate the percentages had been determined on samples higher in unsaturated fatty acids. Second, some diseased samples contained suspended foreign particles which caused the oil to be unclear. Oil in diseased seed was also higher in palmitic, stearic, arachidic, behenic and lignoceric fatty acids than in seed from the uninfected parts of the same heads as determined by gas chromatography. The effects of these alterations on oil quality is not well defined.

Seed and Oil Yield

Generally, all seed samples from infected plants were higher in moisture content (Table I). We believe this high moisture was a secondary disease effect and that it does not indicate immature seed development. The Rhizopus infection must have interfered with the dry down of all seed on the head, whether the seed were in the infected area or not. Dry seed weights were reduced on all areas of the heads of plants infected with Rhozopus, even on the portions that appeared to be healthy and that were uninfected by larvae of the sunflower moth. Dry seed weight for infected heads was 81% of that for healthy heads. This seed yield decrease was less than expected based upon field observations where 60% yield reductions have occurred. Possibly, time of infection and weather (especially humidity) affect the severity of the disease. Because of the added effect of low seed oil content from infected heads, diseased plants yielded only 55% as much oil as healthy plants. Thus, both weight of seed as well as oil percentage of seed were reduced significantly.

Percent unfilled achenes was greatest in the samples from the Rhizopus-infected part of the head. The frass-covered and uninfected areas were not significantly different from the control in this regard. The Rhizopus must have attacked some seed prior to, or immediately after fertilization, producing empty pericarps. Later, the disease must have had a systemic effect on seed in adjoining, but uninfected parts of the head. This effect caused the reduced seed weights mentioned above.

Insect Damage and Disease Association

The average percent of the sampled heads covered with Rhizopus and the percent covered with frass were 29.4 and 60.7, respectively. Percent frass was used to estimate the damage caused by the sunflower moth. This measurement was positively correlated ($r = 0.24$) with disease damage (percent Rhizopus). This association between the insect and disease has been reported (3), and is further verified by this data. Head diameter was positively correlated with percent Rhizopus ($r = 0.28$) and negatively correlated with percent frass ($r = -0.24$). The reasons for these associations are not clear.

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