A CYTOPLASMIC DETERMINANT FOR LOW LEVELS OF SATURATED FATTY ACIDS IN SUNFLOWER OIL

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Summary

Concern about the dietary intake of saturated fats has led to the development of vegetable oils with decreased levels of saturated fatty acids. In order for sunflower to maintain a competitive position in world vegetable oil markets, similar developments are necessary. We report the discovery of a cytoplasmic determinant for low levels of saturated fatty acids in sunflower oil. A variant cytoplasm has been identified which, when used as the maternal parent in sunflower inbreds and hybrids, produced oil in seeds with less than 6% total palmitic and stearic fatty acids. Certain genotypes in this cytoplasmic background produced seeds with oil having less than 1% stearic acid and less than 3% palmitic acid. The effect of the variant cytoplasm on decreasing saturated fatty acid synthesis in seeds was independent of the cropping region. By reducing the saturated fatty acid levels to less than 50% of normal sunflower oil, the unsaturated fatty acids were elevated. This specialty oil is suited for both food and industrial applications.

Introduction

Sunflower oil consists primarily of triacylglycerols having palmitic, stearic, oleic, linoleic, and linolenic fatty acids. Palmitic and stearic acids are saturated fatty acids (SFA) that have been demonstrated in certain studies to contribute to an increase in the plasma cholesterol level, a factor associated with heart disease. Vegetable oils having high content of the unsaturated fatty acids, such as oleic and linoleic, may have the ability to lower plasma cholesterol as compared to oils rich in SFA. Normally palmitic and stearic acids comprise about 10-12% of the total fatty acids in sunflower oil (Dorrell, 1978).

Research in sunflower generally has emphasized the alteration of the percentages of oleic or linoleic acids (Soldatov, K. I., 1976; Urie, A. L., 1985; and Simpson et al., 1989). Palmitic acid levels in sunflower oil also have been increased (Ivanov et al., 1988). No previous research has been reported in sunflower on genetic mechanisms that reduce the level of SFA in sunflower oil. We report here the discovery of a cytoplasmic determinant that reduces the amount of SFA in sunflower oil from seeds of plants having the variant cytoplasm.

Materials and Methods

Emasculation and inbred line development were done according to usual sunflower methodology (Fick, 1978; Knowles, 1983; Skoric, 1988; and Knowles, 1989). Pedigree selection on inbred maintainer lines was done through six generations following the initial emasculated cross. Conversion of maintainer lines to cytoplasmic sterility (cms) began when maintainer lines were in the third generation of self pollination. Cytoplasmic male sterile source, PET 1, derived from Helianthus petiolaris Nutt. (Leclerq, 1969) was used for the development of cms counterparts of maintainer lines.

Beginning in the sixth generation of inbreeding, maintainer lines were analyzed for fatty acid composition. Seeds from self-pollinated captiula were analyzed either individually or in bulk samples. An analysis was done each generation on seeds of cms lines from paired crossing beginning after the third backcross. New lines were tested in hybrid combinations. Seeds from self-pollinated hybrid plants were analyzed for fatty acid composition. Both lines and hybrids were grown in diverse environments when possible to determine the stability of the composition of the fatty acids. All fatty acid analyses were done by capillary gas chromatography.

Results

Following fatty acid analysis of many pairs of cms and maintainer lines grown in Woodland, California, it was noted that the cms line of a single pedigree inbred line had a lower level of SFA in oil of its seeds than that of its maintainer (Table 1.). Pairs of cms and maintainer lines showing this trait were designated 8904W--F (cms) and 8904--G (maintainer). Reduced total SFA in the cms lines was achieved by a significant decrease in stearic acid levels when compared to the maintainer line. Line 8904W06F had a total SFA less than 4%. Oleic acid content was higher in cms lines than in maintainer lines.

Additional pairs of cms and maintainer from the 8904W inbred pedigree were made in Kekaha, Hawaii. Fatty acids analysis of seeds from capitula of plants in these pairs confirmed the trait under Hawaiian conditions (Table 2.). While palmitic acid in seeds was in general slightly higher in both cms and maintainer lines when grown in Hawaii, stearic acid was still greatly reduced in the cms lines compared to the maintainer line. The overall effect resulted in a sunflower oil with decreased levels of SFA when grown under tropical conditions.

Table 1. Fatty acid composition of oil from bulk of five seeds of paired selections of cms (F) and maintainer (G) line 8904W grown in Woodland, CA.

Selection	Total SFA	% Fatty acid 18:0	18:0	18:1	18:2
8904W04F	6.1	3.9	2.2	89.9	4.0
8904W04G	9.9	3.5	6.4	86.2	3.9
8904W06F	3.9	2.0	1.9	90.4	3.7
8904W06G	8.1	2.2	5.9	86.6	3.2

Table 2. Fatty acid composition of oil from bulked seeds of paired selections of cms (F) and maintainer (G) line 8904W grown in Kekaha, Hawaii.

Selection	Total SFA	% Fatty acid 16:0	18:0	18:1	18:2
8904W03F-1	7.0	4.8	2.2	88.1	4.3
8904W03G-1	8.5	3.5	5.0	87.9	3.0
8904W03F-2	6.7	4.9	1.8	88.6	4.2
8904W03G-2	8.3	3.8	4.5	88.2	2.9
8904W03F-3	6.9	4.9	2.0	88.1	4.6
8904W03G-3	9.0	3.7	5.3	87.4	3.0
8904W06F-1	6.7	4.6	2.1	88.9	0.2
8904W06G-1	10.7	3.8	6.9	86.1	0.4

Cytoplasmic male sterile lines showing the trait for reduced total SFA were crossed with restorer lines to make hybrids. Hybrids were planted in Montech, France, Venado Tuerto, Argentina, and Woodland, California. These hybrids were designated 8W1070 and 8W1075. Fatty acid analyses of composite seed samples from self-pollinated capitula were done for each environment where grown and are shown in Table 3. The effect of the cytoplasm was evident in hybrids in all environments. Stearic acid was greatly reduced. Certain bulk samples had less than 1.0% stearic acid and less than 4.0% palmitic acid. In France, hybrid 8W1070 showed a total SFA of only 3.8%. Since SFA were decreased, unsaturated fatty acid levels were elevated. Oleic acid content in oil exceeded 93% in two samples from France and Argentina.

Discussion and Conclusion

Cytoplasmic effects on SFA synthesis in oil of sunflower have not been reported previously. The cytoplasm described here that reduces the synthesis of SFA is a variant of the PET 1 cytoplasm that also confers male sterility. The level of SFA in oil has been reduced for all genotypes which have been substituted into the variant cytoplasm. Such a reduction in SFA causes a relative enhancement of oleic and linoleic fatty acids, the extent of which is dependent on the nuclear genotype. Fatty acid analyses of other inbred lines with PET 1 cytoplasm and their respective maintainer lines with normal cytoplasm both of proprietary and public origin have not shown significant variation for SFA levels (data not presented). The combination of the low SFA trait with male sterility in the same cytoplasm provides for the production of hybrid sunflower using existing sunflower germplasm. We consider this variant cytoplasm to be unique. We refer to it as LSPET 1, indicating the trait for low saturates that the cytoplasm confers.

Table 3. Fatty acid composition of oil from bulked seeds of hybrids 8W1070 and 8W1075 grown in three environments using 8904W06F and 8904W03F, respectively, as female parents.

Hybrid	Location	Total SFA	% Fatty acid 16:0	18:0	18:1	18:2
8W1070	France	3.8	2.8	1.0	94.1	2.1
	California	5.8	4.5	1.3	89.4	4.8
	Argentina	6.3	3.7	2.6	89.6	3.9
8W1075	California	4.8	4.0	0.8	89.9	5.0
	Argentina	4.6	3.4	1.2	93.5	1.5
6440 Normal	California	12.8	7.0	5.8	20.8	66.2

Sunflower oil having less SFA will compete with other vegetable food oils that claim low content of saturated fatty acids. The correspondingly high levels of unsaturated fatty acids also make this oil ideal for industrial use. It is clear that sunflower oil having less than 6% total SFA can be produced regularly in sunflower growing areas by use of the novel cytoplasm identified here. With particular attention to the nuclear genotypes used in conjunction with this cytoplasm, production of sunflower oil routinely having about 4% total saturated fatty acids is feasible.

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