Introduction of the reactive functional groups via Diels-Alder reaction opens a new line of chemicals which can be derived from these intermediates of jojoba oil.

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Effect of Temperature on Soybean Seed Constituents: Oil, Protein, Moisture, Fatty Acids, Amino Acids and Sugars

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ABSTRACT

Soybean plants were grown at day/night temperatures of 24/19 C until the beginning of seed development, and then transferred to 5 different temperature regimes (18/13, 24/19, 27/22, 30/25 and 33/28 C) in the CSIRO phytotron. Mature seeds that developed under these conditions were analyzed for variances in composition. Fatty acid composition was strongly affected by temperature: linolenic and linoleic acids decreased markedly whereas oleic acid increased as the temperature increased; palmitic and stearic acids remained unchanged. Oil content was positively correlated with temperature, and protein content increased at the highest temperature. Of the sugars analyzed, sucrose concentration decreased by 56% with a 15 C increase in temperature, and stachyose showed a slight reduction; other sugars remained unchanged. Amino acid composition was generally stable; however, methionine increased with increased temperature during seed development. Moisture content was unaffected.

INTRODUCTION

It is generally thought that oilseed plants grown under a warmer climate produce seeds containing less highly unsaturated fat than when grown under a colder environment. For example, Collins and Howell (1) found in soybeans that linoleic and, more strongly, linolenic acids are negatively correlated with temperature, using Weather Bureau data to substantiate the difference in growing temperatures of the locations studied. Howell and Collins (2), using both location and greenhouse studies, confirmed these results. Collins and Sedgwick (3) found that soybean varieties grown at the northern end of their range produced oil 1-2 percentage points higher in linolenic acid and 3-6 higher in linoleic acid than when grown at the southern end of their range. More recently, Chapman et al. (4) showed that soybeans grown at Tifton, Georgia (with an average daily temperature of 25.7 C), have 2% lower linoleic and 20% lower linolenic acid content, with 11% higher oleic, than the same varieties grown at Blairsville, Georgia (with an average daily temperature of 18.0 C).

Temperature has also been shown to affect total oil and protein content of soybeans. Howell and Cartter (5,6) reported a positive correlation between maximal temperature and oil percentage. Additionally, both a negative (7-9) and a positive (4) correlation between protein and oil have been reported. Howell and Cartter (6) found that protein was stable with relation to temperature, but non-protein nitrogen increased as the temperature rose.

Little work has been done on the other constituents of the soybean seed as they relate to temperature during seed growth. Chapman et al. (4) found that moisture content decreased as growing temperature increased. Hymowitz et al. (9) reported that total sugar content of the soybean seed, as well as sucrose alone, is positively related to total oil and negatively to total protein. However, no correlation was made between this component and temperature, nor has the relationship between amino acids and temperature been explored.

None of the studies discussed above were conducted under completely controlled environmental conditions. The present experiment undertook this task, using soybeans of one variety (Fiskeby V) that were grown in a phytotron under 5 different controlled day/night temperature regimes during seed maturation. All the major constituents of soybeans were analyzed: oil and fatty acids, protein, sugars, amino acids and moisture.

EXPERIMENTAL PROCEDURES

Dr. D.B. Egli kindly supplied soybeans, variety Fiskeby V, which had been grown in the CSIRO phytotron, Australia, at day/night temperatures of 24/19 C (8-hr day) until the beginning of seed growth, and then shifted to the following day/night temperature regimes until maturity: 18/13 C; 24/19 C; 27/22 C; 30/25 C; and 33/28 C (10). All analyses of seed constituents were run in duplicate.

Oil content was determined by Butt Extraction (11) with petroleum ether as solvent. Fatty acids were esterified according to the method of Metcalfe et al. (12), and analyzed on a Varian 3700 gas chromatograph using a 6 ft × 2 mm glass column packed with 5% LAC-2-R 446 on Gas-Chrom Q at 180 C.

Amino acid composition was determined by hydrolyzing a known amount of ground, defatted sample and an internal standard (Norleucine) in 6 N HCl and analyzing on a Glenco MM-100 amino acid analyzer. Average nitrogen recovery was 95%. Methionine and cystine were determined according to the method of Moore (13).

Protein content was found by the standard Kjeldahl procedure using ground whole seed. Moisture was determined by grinding the beans to a fine meal, drying them for 3 hr at 130 C and measuring the weight lost.

Sugars of the defatted meal were analyzed by the method of Black and Glover (14).

RESULTS AND DISCUSSION

Fatty acid composition was strikingly affected by temperature during seed maturation (Fig. 1). Beans produced by plants grown in cool temperatures (18/13 day/night) had 16.4% linolenic acid, whereas those grown under hot conditions (33/28 day/night) had only 5.0% linolenic acid. This is a reduction of ca. 70%, which is much greater than any previously reported. Linoleic acid was reduced by 27%–from 55.8% under cool days and nights to 40.3% under hot.

As linoleic and linolenic acids decreased, oleic acid showed a correspondingly sharp increase (196%), from 13.1% (cool conditions) to 38.7% (hot conditions). Palmitic and stearic acids remained essentially unchanged.

The decrease of the more highly unsaturated C_{18} acids, with a concomitant increase of the C_{18} monounsaturate, suggests that the dehydrogenation reaction is limited at warmer temperatures. Harris and James have suggested that temperature controls dehydrogenation by influencing the amount of O_2 available, and that oxygen is the rate-limiting factor for the reaction (15). As the temperature increases, oxygen becomes less soluble in the cytoplasm; therefore, dehydrogenation would not occur to the extent possible under cooler temperatures. This hypothesis is supported by the present results.

Oil content increased markedly (37%) as the temperature increased (Fig. 2). The sharpest rise occurred between 24/19 C and 27/22 C; temperatures warmer than the latter during seed growth only produced an increase of one percentage point. Protein content was fairly stable between 18 and 30 C, but increased significantly at a day temperature of 33 C (Fig. 2). Hence, like Chapman et al. (4), these results show a positive correlation between protein and oil.

Of the sugars found in soybeans, glucose, fructose and raffinose levels were unaffected by change in temperature, whereas stachyose showed a slight decrease at the highest temperature tested (Fig. 3). It has been suggested that sugars, especially stachyose, contribute to the poor food quality of soybeans in reference to flatulence (9). If this is the case, growing the beans in a warmer climate may help alleviate this problem. Sucrose content decreased strikingly as the temperature increased: at 18/13 C, the sucrose content was 8.1%, but at 33/28 C, the level dropped to 3.6%; a reduction of ca. 56% (Fig. 3). Hence, a negative correlation between sugar and oil content was found, in opposition to the report by Hymowitz et al. (9).

Most amino acid levels were unchanged. However, methionine showed a substantial increase at the warmest temperature (Table I). As Howell et al. (16) have noted, methionine is the limiting amino acid in soybeans. The ability to increase this component by growing the beans

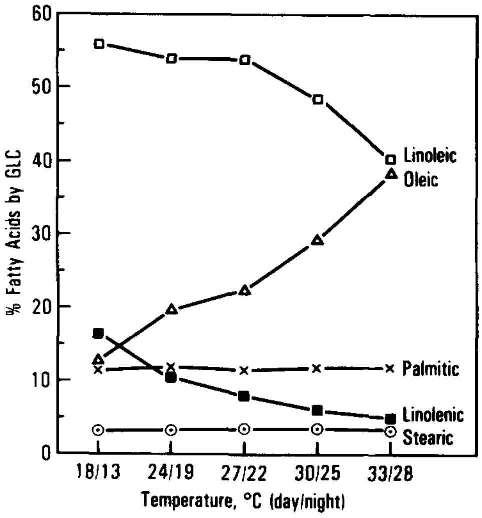

FIG. 1. Temperature vs fatty acid composition (area %).

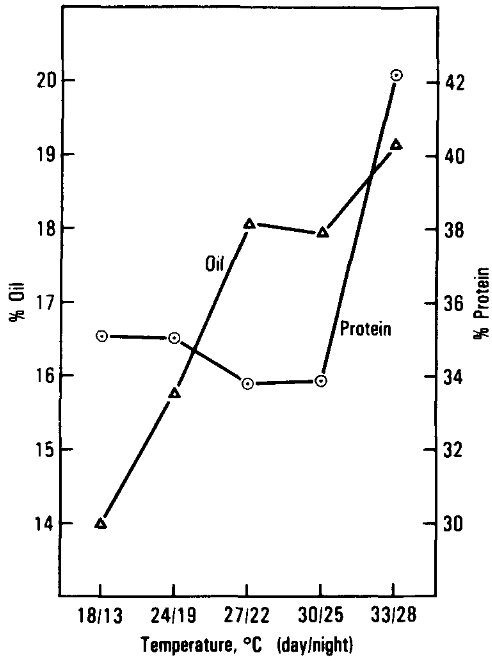

FIG. 2. Temperature vs total oil and protein content (% wt of whole seed).

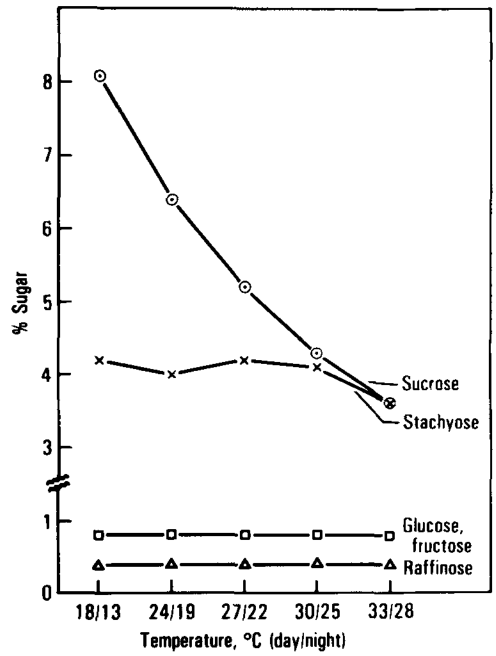

FIG. 3. Temperature vs sugar composition (% wt of defatted meal).

TABLE I

Temperature vs Amino Acid Composition

Amino acid	Temperature (day/night) C				
g/16 g N	18/13	24/19	27/22	30/25	33/28
Aspartic acid	11.7	11.9	12.0	12.0	12.2
Threonine	4.0	4.0	4.0	3.9	4.0
Serine	5.1	5.2	5.2	4.6	5.1
Glutamic acid	18.0	17.8	17.7	18.2	18.5
Proline	5.1	5.2	5.1	5.1	5.3
Glycine	4.4	4.4	4.4	4.5	4.5
Alanine	4.4	4.3	4.4	4.3	4.3
Valine	4.8	4.7	4.8	5.2	4.7
Isoleucine	4.6	4.7	4.8	5.0	4.7
Leucine	7.8	7.8	7.8	7.7	7.6
Tyrosine	3.9	3.9	4.0	3.9	3.7
Phenylalanine	5.3	5.2	5.2	5.3	5.1
Lysine	6.9	6.9	6.8	6.8	6.7
Histidine	2.7	2.7	2.7	2.6	2.6
Arginine	8.8	8.2	8.0	8.0	8.3
Methionine	0.72	0.67	0.76	0.98	2.53
Cystine	0.99	1.09	1.26	1.43	1.16

under warmer temperatures would be a distinct advantage.

Moisture content (9.3-10.1%) was unaffected by temperature, in contrast to the findings of Chapman et al. (4). It should be noted that moisture content may be greatly influenced by storage conditions after harvest. However, as all seeds were stored in the same place under the same conditions, any differences in moisture content caused by growing temperature probably would be noticeable.

Thus, ambient temperature during seed development does profoundly affect the composition of the soybean seed. The quality of the seed is greatly improved when grown under warm (33/28 C day/night) conditions. Linolenic acid, which causes off-flavors and bad odors of soybean oil, is strikingly reduced under these conditions. Stachyose, a contributor to the poor food quality of soybeans, is also lowered. At the same time, the total amounts of oil, protein and methionine are increased. The genetic make-up of the seed will determine the range within which environmental influences can operate on seed composition. For the variety Fiskeby V, that range was found to be great.

ACKNOWLEDGMENT

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